Jörn Thiede

For Jörn Thiede
with kind regards
Sincerely
Eyerhard 95

Blue Planet Prize 1994

Commemorative Lectures Report

United Nations University International Conference Hall
Tokyo, Japan

November 3, 1994

THE ASAHI GLASS FOUNDATION

This report contains the proceedings of the 1994 Third Blue Planet Prize Commemorative Lectures and Follow-Up Discussions, held in the International Conference Hall of the United Nations University in Tokyo on November 3, 1994.

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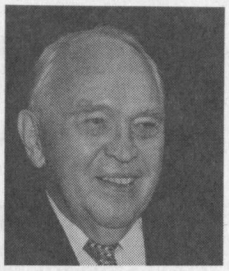
Professor Dr. Eugen Seibold



After obtaining his doctorate from the University of Tübingen in 1948, Professor Seibold embarked on a distinguished career as a researcher and educator in the field of marine geology. His more than 30 years of pioneering research in the oceans of the world, highly acclaimed for its accuracy and interdisciplinary approach, has produced a body of work relevant to solving today's global environmental problems. In addition to teaching countless students, Professor Seibold has served as the head of several major scientific organizations and is currently Professor Emeritus at the University of Kiel.

Discussant **Professor Yoichiro P. Murakami**

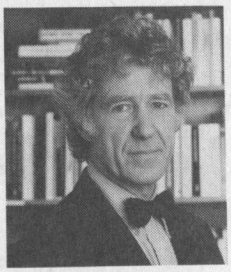
Professor Murakami received his academic degrees from the History and Philosophy of Science Department and the Graduate Program for Comparative Studies of Culture at the University of Tokyo. In 1989, he was appointed to the University of Tokyo's Research Center for Advanced Science and Technology, where he has served as director since 1993. Professor Murakami's academic interests range from the history of science to environmental ethics. He is an elected member of the Pontifical Academy of Social Sciences.

14:55 Intermission

15:10 **Part Two: Development and Implementation Award Winner's Lecture and Follow-Up Discussion**

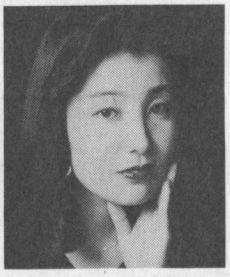
"Environmental Revolution"

Lester R. Brown



Lester R. Brown, with a degree in agricultural science from Rutgers University and extensive farming experience, joined the U.S. Department of Agriculture's Foreign Agricultural Service in 1959. In 1974, Mr. Brown founded the Worldwatch Institute, a private nonprofit research organization devoted to the analysis of global environmental issues. Through numerous publications and his work as president of the Institute, Mr. Brown has played a major role in shaping the global environmental movement of the late twentieth century.

Discussant **Kei Hata**

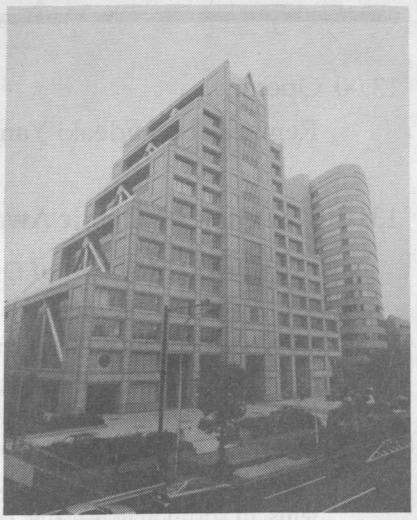


After earning a degree in French from Waseda University, Ms. Hata joined NHK and served as anchor of the "Seven O'clock Evening News." She left NHK in 1989 to pursue a free-lance career in journalism and, in 1992, was invited to Paris by the European Union to conduct research on establishing cultural aid programs. A founding member of the Japan Women's Global Environment Network International, Ms. Hata frequently deals with environmental issues.

17:00 Closing

Part One

Academic Award Winner's Lecture and Follow-Up Discussion



"The Seafloor as Part of Our Environment"

Professor Dr. Eugen Seibold
Professor Emeritus at the University of Kiel

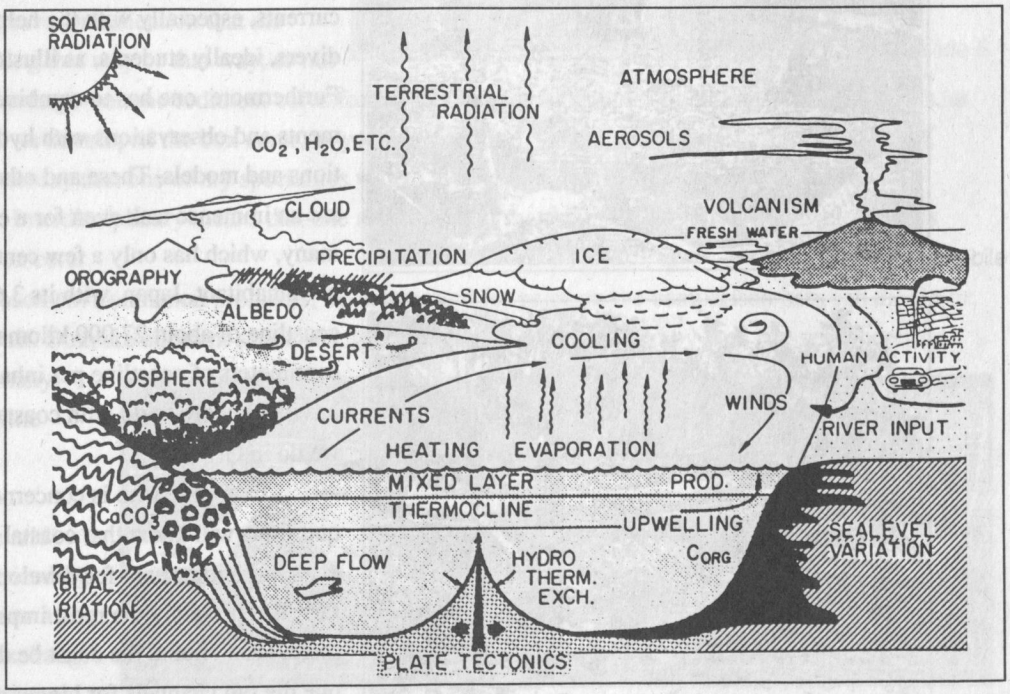
To the audience of a Blue Planet Prize lecture, it is well known that our Earth is the only planet with fluid water and that this is the precondition for both our oceans and for life. Of course, it is also known that the oceans cover more than two-thirds of our globe, of our blue planet.

This means that there are many interactions between sea and land environments, as you see in slide 1. Through evaporation, the oceans supply the remaining third of our globe, the land masses, with rain and snow. With their currents, they transport heat from the equator to polar regions and influence the wind system. The oceans are therefore a weather machine controlling continental droughts or river floods, together with agriculture or traffic. In this way, they even influence our daily life. Long-term variations in this dynamic system determine climatic fluctuations with drastic consequences for our environment.

Oceans are as deep as our highest mountains are high. Ocean dimensions, including their water masses, are huge. They correspond to 160 times the water and ice on land and to 100,000 times the water in the atmosphere. Therefore, the oceans are buffers for all sorts of variations. They may store or release heat or carbon dioxide (CO_2).

Most of these factors which characterize oceanic research require much comprehension on the part of the public up to the governments, and because humankind has begun to influence some of these factors a number of some relevant issues concerning the oceans were defined in 1992 in Rio in a 540-page document, *Agenda 21*. This came as a result of the United Nations Conference on Environment and Development (UNCED).

The Third Blue Planet Prize Academic Award is given to a marine geologist, and I can only accept this honor if I see myself as a representative of many colleagues around the world. What is a marine geologist? A marine geologist investigates the present situation of the seafloor and the processes which shape it. Furthermore, he tries to



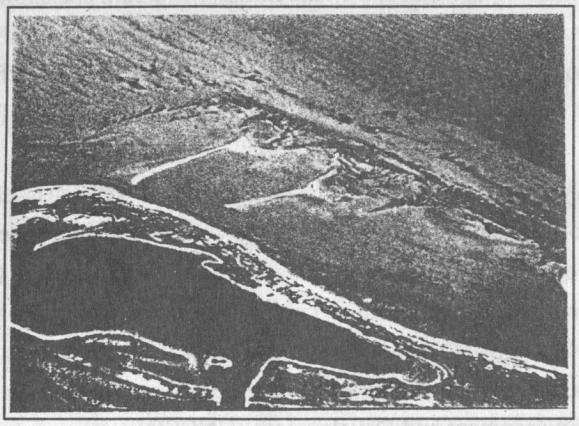
slide 1

learn from the layers beneath the seafloor, i.e., he tries to learn from the past. With this knowledge from the present and the past, he has a responsibility to comment also on future developments if he is able to do so with scientific reasoning, and I would like to stress this aspect.

With the following remarks, I shall try to illustrate some of these points with a few examples from my own work during the last decades. I would like to invite you to come with me to the coasts, where I shall stress coastal management, then to the shallow seas with some remarks about pollution, then to the continental margins with their potential petroleum resources, and finally to the deep sea with its sediments as archives for historical climatic changes. Let us go to the coasts.

Coasts

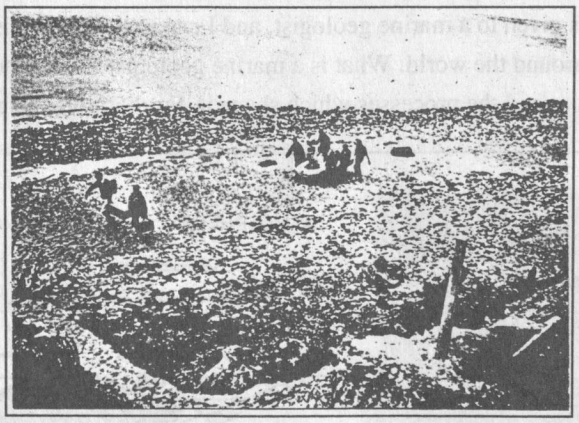
For two decades after the end of World War II, we had no oceangoing research vessel in Germany. Therefore, we concentrated our efforts on the North Sea and Baltic Sea and their coastal regions. In any case, the marine environment begins at the coasts and with its many interactions with the neighboring inland. It is said that 80% of the world's population is settled in the 50-kilometer zone along the shores.



slide 2

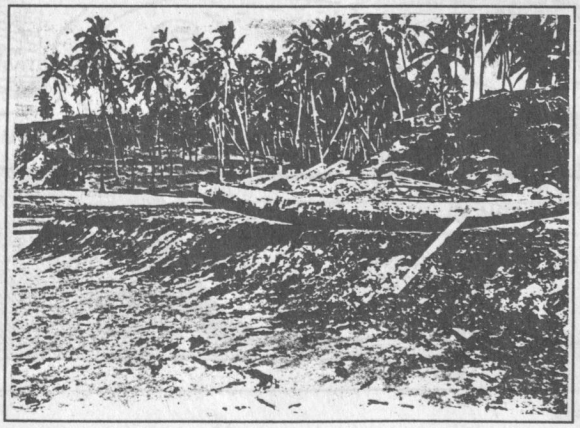
The coasts are very peculiar landscapes because they are shaped by processes belonging equally to the hydrosphere, the atmosphere, and the lithosphere. Water, air, and rocks must therefore be studied.

Waves and currents may be destructive and cause coastal erosion. They can as well be constructive in transporting sand and forming offshore bars, as in the Baltic, shown in slide 2. Of course, harbor authorities have to fight against this type of sand transport. For them, sand and mud coming from offshore or from rivers is a kind of pollution.



slide 3

To obtain qualitative or even quantitative data, one uses tracer sands and one has to observe the sea bottom carefully for bed forms indicating currents, especially with the help of enthusiastic divers, ideally students, as illustrated in slide 3. Furthermore, one has to combine all these measurements and observations with hydrodynamic calculations and models. These and other coastal problems are an immense task even for a country like Germany, which has only a few centimeters of coastline per inhabitant. Japan, with its 3,600 islands and a coastline of about 27,000 kilometers, has about 23 centimeters of coastline per inhabitant and therefore has much more to do with coastal management than we do in Germany.



slide 4

Everyone who is concerned with such questions will know that coastal management is even more important for developing countries. In fact, it is probably the most important oceanic aspect there. How should the coast be developed? Should one dig out channels for bigger ships and harbors?

Establish water-dependent industries, like nuclear reactors? Protect lagoons for breeding marine animals? Or protect sandy beaches for tourism? Use beach and dune sands as mineral resources? In many cases, one special use excludes others. Therefore, the marine geologist has to give advice in examining the consequences of different potential uses. But before that he must try to understand the processes behind the screen.

I would like to give only one example. In slide 4 you see a part of the coast of India. Tropical weathering conditions destroy quartz and other minerals more than some so-called heavy minerals and ore particles containing iron, titanium, gold, platinum, thorium, zirconium, and so on. Near-shore processes can concentrate them to so-called placer deposits. India is famous for such beach placers around the semicontinent.

How do placers originate? I cannot go into detail, but the processes involved have much in common with panning for gold, as we could demonstrate in beach studies. Of course, this is a problem for fundamental research, but its investigation helps toward exploring placers if you apply this principle to beaches where monsoon waves attack dune sands, like in India. The combination of both is the optimum for placer exploration.

A geologist always has in mind that the sea level has risen by some 100 meters since the melting of the huge continental ice masses some 15,000 years ago. Therefore, former beach sand placers can be expected offshore. Of course, all other mineral resources, including oil and gas, are also products of concentration by nature to be studied by geologists.

We know as well that at present the sea level is rising in most regions by some millimeters per year—here in Japan, too—and that this rise can be accelerated by further global warming, a dramatic threat for lowlands and many islands. But it would lead too far to treat these aspects today. Now let us go to the second chapter, the shelf seas.

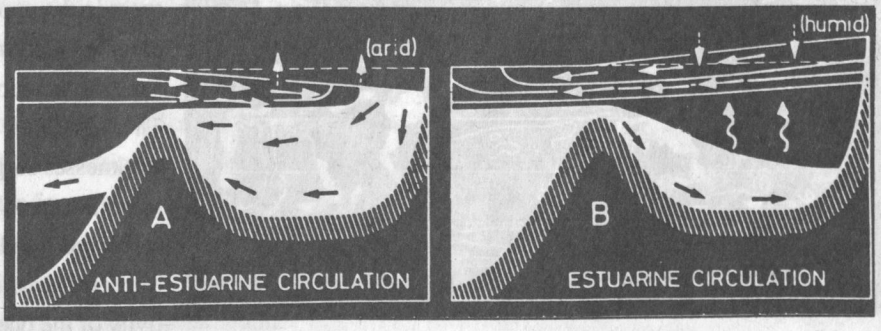
Shelf Seas

Offshore we enter the so-called shelf sea with water depths up to about 200 meters. Here we need well-equipped ships and special instruments to study morphological features of the seafloor or to recover sediments and organic remains from the surface or from cores in the sediments. For example, underwater side-scan echo sounders reveal details down to the centimeter, such as ripple marks and other current indicators, where you have an indication that the bottom current is flowing this way or that way, or not at all. In order to obtain large-volume sediment cores for the distribution of samples to all interested specialists, at the University of Kiel we developed the box corer, as you see in slide 5, aboard the *Meteor* in the Persian Gulf. It was emphasized yesterday that one of my specialties was to always stress interdisciplinary approaches for solutions to problems. Interdisciplinary means that one needs a lot of material, and therefore we developed this special sampler, the box corer.

slide 5

Trying to approach environmental problems, I concentrated for years on the comparison between the Baltic Sea and the Persian Gulf. Both are adjacent seas to the great oceans and are enclosed by land masses. Therefore, land climate dictates many processes in these marine environments. This is illustrated in slide 6.

The seas in the arid climatic belt, characterized by excess evaporation, have a common and typical exchange pattern with the open ocean:



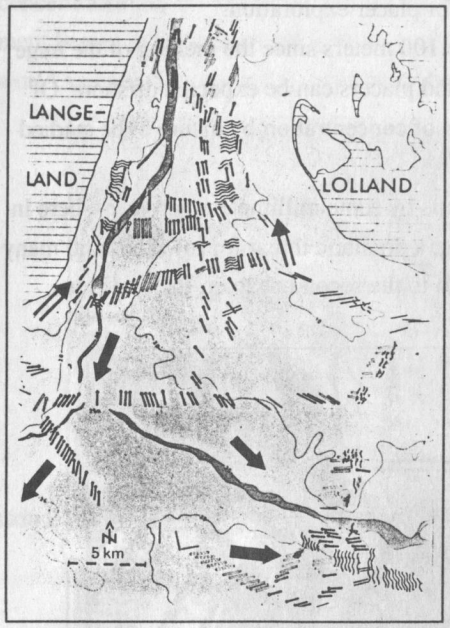
slide 6

shallow water flows in and deep water flows out. Typical examples are not only the Gulf, but also the Mediterranean Sea and the Red Sea.

Here the loss of water by evaporation greatly exceeds the influx from rain and rivers. Thus, the sea level drops and water enters from the open ocean at the surface to replace the losses in the basin. Evaporation in the basin increases the salinity, and therefore the density of the water, which makes it sink. This sinking is a motor for outgoing currents of heavier deep water, flushing out many kinds of pollution.

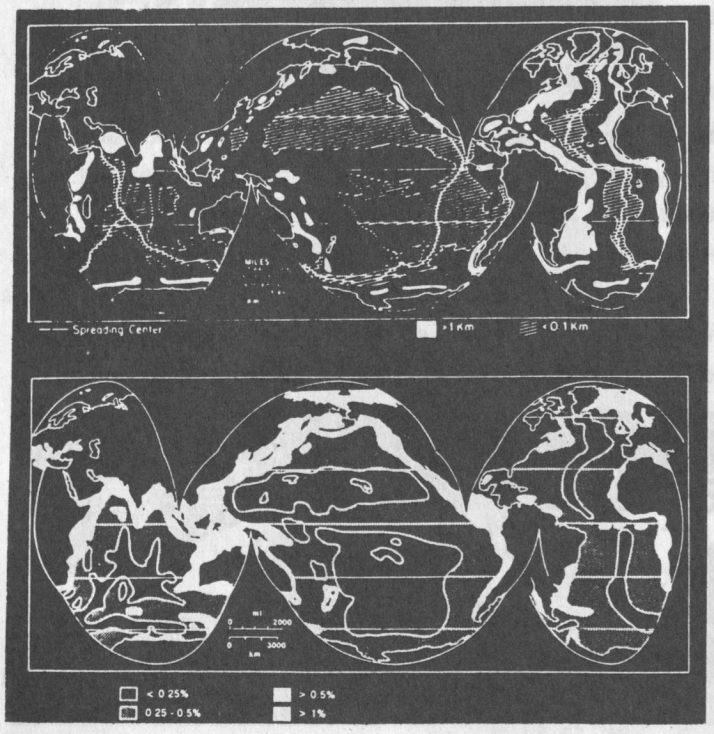
The reverse situation can be studied in the Baltic, Black Sea, and in northern fjords: shallow water flows out and deep water flows in, because here rain and river influx exceed evaporation.

One of the consequences of the influx of heavier, saltier bottom water to the Baltic is a relatively stable stratification of the adjacent seawater column, preventing oxygen from the air to reach the deeper parts where hydrogen sulfide (H_2S), a poisonous gas, can develop and kill everything. Pollution by sewage discharge from about 20 million people and industrial wastes, together with fertilizers from agriculture, increase organic productivity and therefore deep-water oxygen deficiency—a continuous threat to surface waters and the organisms in them, because H_2S can reach the surface when there are storms.



slide 7

I would like to bring just one example from our fieldwork to your attention. These are investigations in the channels of the North Sea going to the western part of the Baltic, as shown in slide 7. Here you have Langeland and Lolland, two Danish islands. And you see the many small arrows, which represent our investigations of the sea bottom to discover current indicators. The summary of these current indicators is shown with larger arrows. You see that the full, larger arrows show the bottom-water influx, and the other two larger arrows in shallow water prove that the model is correct, that we have outflow of surface water. Now let us go to the continental margins.



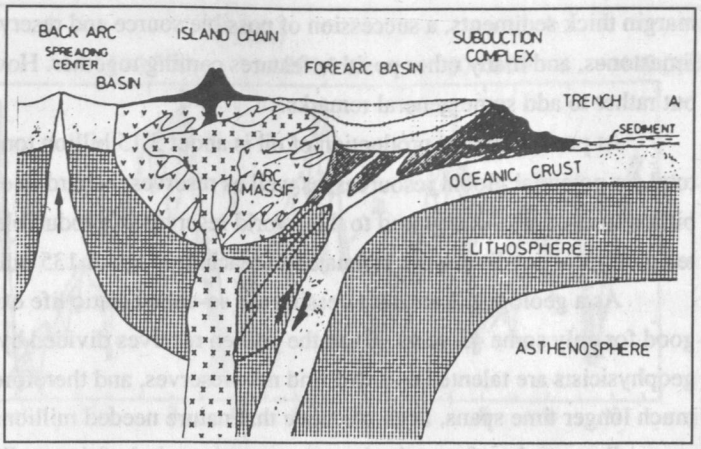
slide 8

Continental Margins

The continental margin begins with the shelf. We continue on, crossing the continental slope and rise to water depths of about 4,000 meters, where the deep sea, strictly speaking, begins. I would like to stress only one aspect, the opportunities for finding offshore oil and gas underneath our continental margins.

If you look at slide 8, you see it is divided into two diagrams, and of course it is very complicated, but just look at the white spots in the upper diagram and the lower diagram. Continental margins are the dumping sites for the debris coming from the continents. Therefore, they may collect sediments of thicknesses surpassing 10 kilometers. These are the white spots in the upper diagram. Furthermore, these sediments contain a high proportion of organic matter because of the high productivity of the oceanic regions around the

continents (lower diagram). Both facts favor the formation of oil and natural gas. This formation and the migration to reservoir rocks require higher temperatures underground and some time in geological dimensions. A sediment cover of one to two kilometers is generally necessary for these processes to happen. As the sediment cover of vast parts of the deep sea is too thin and also too young, more than 80%—and that is a very important figure—of the oceanic seafloor offers no chance for exploration of oil. Only the white areas of the upper part of slide 8 are promising.



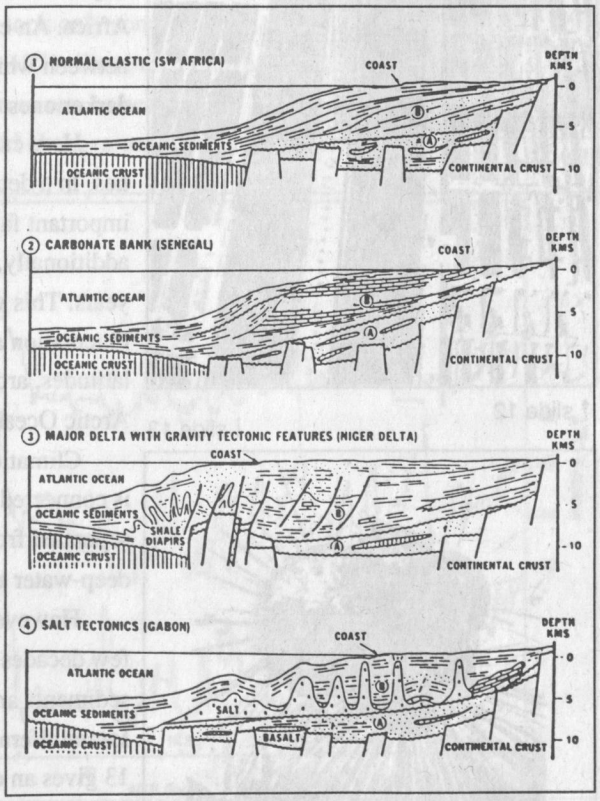
slide 9

This very disappointing figure of 80% is deducible from the concept of plate tectonics, a rather new concept of how the ocean and the ocean crust are formed which I cannot treat here today. This is one of the exciting consequences of the application of an academic hypothesis, and it clarifies even important aspects of global energy resources.

Plate tectonics also sheds light on the character of Japan's continental margin, the nature of which causes many problems. It is a so-called active margin shaping your environment in many respects. A lithospheric plate, as shown in slide 9, sinks beneath another one, accompanied by earthquakes, volcanic eruptions, and extreme disturbances of the sediments there. You see this plate is sinking down underneath Japan, and in this region earthquakes occur, and when going deeper everything is melting, and you get the Fujis here on your islands. The Japan Sea is a very complicated area upon which I will not touch too much now.

slide 10

Now why is it so disappointing for oil companies? First of all, all these movements below are very complicated and create complicated structures, as we could see in the Nankai Trough of Japan between Shikoku and Honshu in a 1990 drilling expedition on the vessel *Joides Resolution.* In slide 10 you see an ancient Japanese demonstrating that on the right-hand side the oceanic crust is going down and that the sediment structures in this geophysical picture are pretty complicated. In addition to that, unfortunately, potential sandy reservoir rocks are here mostly cemented and offer no sufficient permeability for the oil. This is because these sands are of volcanic origin and therefore chemically very reactive. There are a lot of negative points for oil exploration around Japan.



slide 11

In 1975, I worked as co-chief scientist aboard the drill ship *Glomar Challenger* off West Africa, a typical passive continental margin. Please forget all the details of the sequence of typical profiles of a so-called passive continental margin as illustrated in slide 11. But at least you see in all these different types of a passive continental

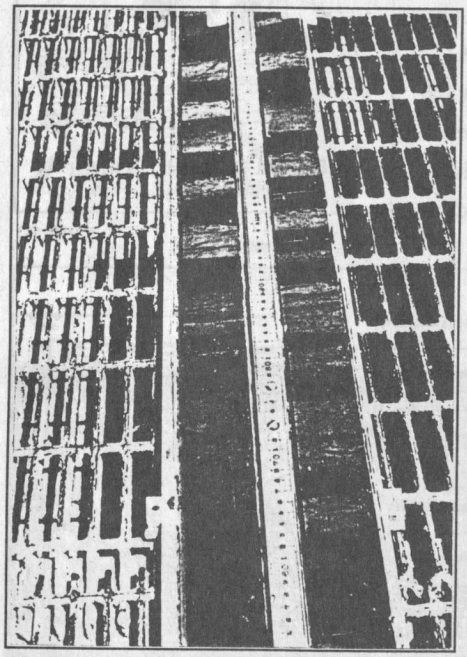
margin thick sediments, a succession of possible source and reservoir rocks like porous sandstones or cavernous limestones, and many other positive features coming together. However, I would prefer not to go into more detail, but rather to add some general remarks.

At present, world production of oil is about 3.15 billion tons annually. Around 30% comes from offshore. A total for potential global resources, as well as reserves, is hard to estimate. World resources may reach 200 to 300 billion tons of oil. As opposed to this, world reserves of producible petroleum under the prevailing economic and technological conditions are estimated to reach only about 135 billion tons.

As a geologist, I am not stressing the so-called static life expectancy of the oil reserves; at present, they are good for only some 43 years, given the proven reserves divided by annual production. But of course, geologists and geophysicists are talented and will find new reserves, and therefore it will last longer. As a geologist interested in much longer time spans, I can calculate that nature needed millions of years to accumulate these resources.

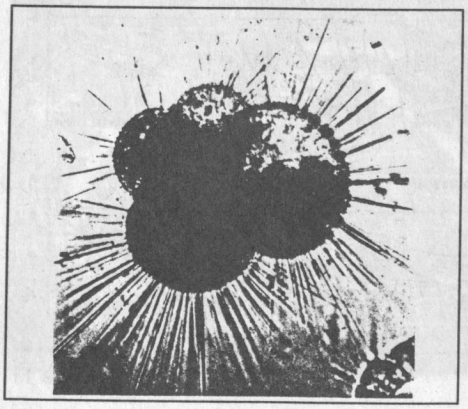
By an order of magnitude, nature over a period of time collected only some 2,000 tons of oil annually: if you divide 300 billion tons, for example, by 150 million years, you get the incredibly low figure of an annual natural production of 2,000 tons. And we use three billion tons a year. Therefore, this ratio is very bad—about 1:1,500,000 or 1:2,000,000. We are thus guilty of incredible exploitation, even robbery, without an eye to future generations.

Even more generally speaking, for me the energy supply for both the industrialized and developing countries should be top priorities on our problem-solving global agenda. Because with energy you can even convert seawater into fresh water for irrigation. It is nonsense, of course, because it is too costly and not energy-efficient, but in principle you can do it. Now let us go to the deep sea.



↑ slide 12

↓ slide 13



Deep Sea

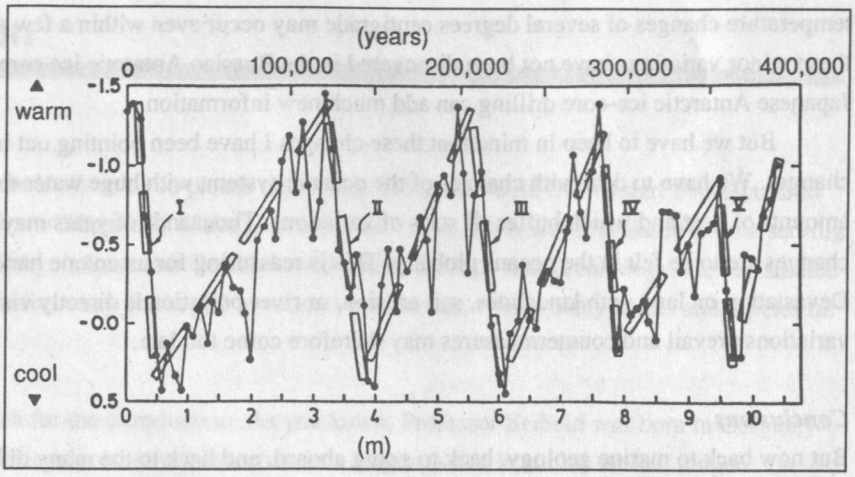
I would like to demonstrate that deep-sea sediments are excellent archives for environmental changes, and with modern methods we can even make up for some losses or disturbances of the archive pages. Here, I concentrate on only one aspect, on rhythmicity in many sequences of deep-sea sediments, as in deep-sea drilling cores off West Africa. An example is given in slide 12. This alternation is a sequence between whitish layers, i.e., layers rich in calcareous particles, and darker ones called marls with higher quartz and clay mineral contents.

How can we explain these sequences? There are many possibilities. In a detailed analysis, we were able to prove that here the most important factor was different dissolution of calcareous particles and, additionally, that the periodicity of the fluctuations was around 40,000 years. This was the situation in the Atlantic some 15 million years ago. Fluctuation at that time was mainly controlled by processes in high latitudes, around Antarctica and in the northernmost Atlantic and in the Arctic Ocean.

Climatically, the Atlantic is the most sensitive ocean because it is connected with both polar seas. The Pacific, on the other hand, is separated from the north by the Bering Strait, which is too shallow for deep-water exchanges.

However, much more sophisticated methods used during the last few decades disclosed truly revolutionary relations between deep-sea sediments and climatic oscillations. One uses tiny organisms like foraminifera whose tests consist of calcium carbonate, $CaCO_3$. Slide 13 gives an example. They contain oxygen which is taken from seawater. The ratio of oxygen 16 to oxygen 18 indicates mainly the volume

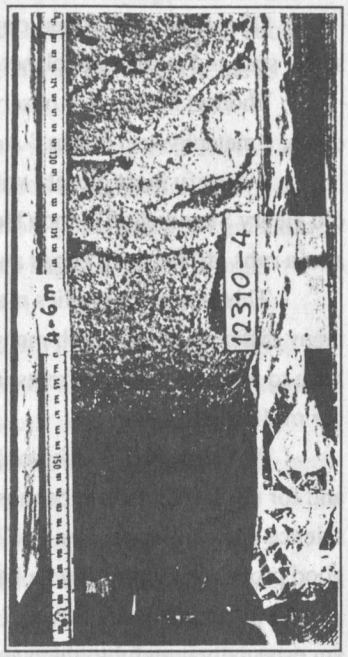
of ice masses stored at any given time, i.e., in colder or warmer phases, on the continents during the last two to three million years, the so-called ice age.



slide 14

From this deep-sea sediment core, which is over 10 meters long, one can give a summarized survey of the last 400,000 years, as shown in slide 14. I included it in a textbook translated into Japanese eight years ago because it looks to me like a musical score with its rhythmic and melodic variations. You see an astonishing rhythmicity. One can easily see prominent 100,000-year cycles for this period. In the curves, downs are colder phases called glacials, and ups are warmer phases called interglacials. Additionally, downs mean lower sea level because of the ice masses stored on the continents. Fortunately, at present we live in an interglacial. Seen geologically, it looks reasonable to say that in some millennia we shall approach a new glacial phase.

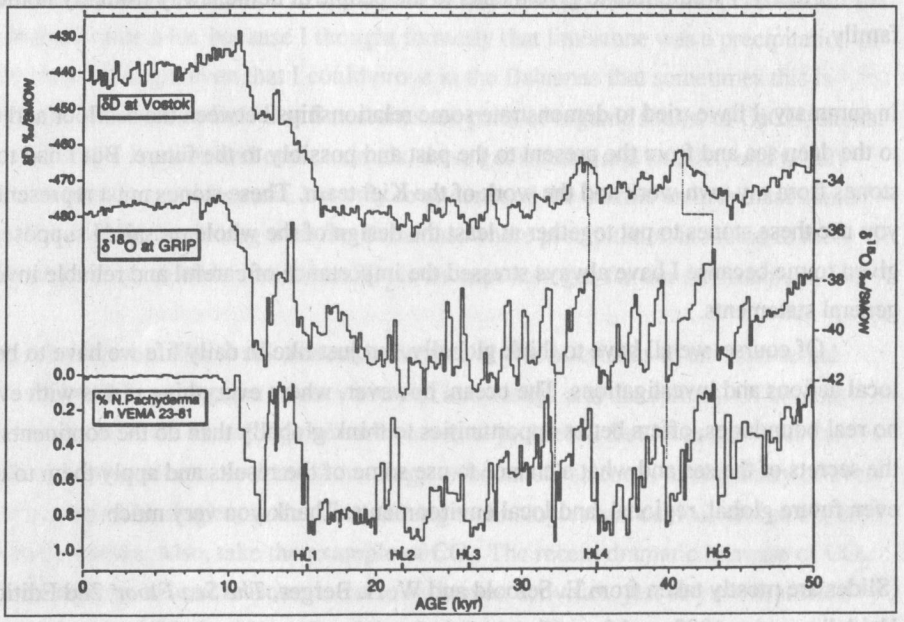
The summary curves also reveal smaller ups and downs. But let us stress only one of the many aspects being discussed at present for possible future climatic fluctuations: How quickly can these fluctuations occur?



slide 15

In a sediment core from the Atlantic off West Africa (slide 15), in about a 5.5-meter core depth you can see a boundary between greenish and greyish colors. It marks the beginning of the last interglacial, some 140,000 years ago. The boundary is very sharp. Therefore, the transition probably took only some centuries to happen. The core was taken on *Meteor* Cruise 25 in 1971. Since then I have emphasized how rapid such transitions of our climatic system can be because the system is nonlinear. We should bear in mind that such rapid changes could occur in the future, too, if we approach a threshold for one or several factors. An increase of global temperatures or growing CO_2 contents may be examples of such factors causing climatic change.

Indeed, many more and partly extremely rapid variations were recently discovered in two Greenland ice cores. In slide 16, you see a lot of ups and downs during the last 50,000 years. According to these results, our colleagues believe that



slide 16

temperature changes of several degrees centigrade may occur even within a few decades. But up to now most of these minor variations have not been discovered in the Russian Antarctic ice core Vostok. Hopefully, the planned Japanese Antarctic ice-core drilling can add much new information.

But we have to keep in mind that these changes I have been pointing out in these ice cores are atmospheric changes. We have to deal with changes of the oceanic system, with huge water masses which store such huge amounts of heat and which buffer all sorts of variations. Thousands of years may elapse before relevant climatic changes are to be felt in the oceans globally. This is reassuring for us on one hand, but alarming on the other. Devastation on land with landslides, soil erosion, or river pollution is directly visible. In our oceans, long-term variations prevail and countermeasures may therefore come too late.

Conclusions

But now back to marine geology, back to going aboard, and back to the many different feelings evoked by the vast oceans.

Of course, cool, sober, objective oceanography and marine geology are only one part of the approach to the seven seas and to our blue planet. We cannot leave out emotion.

Thomas Mann once observed that "the sea is not landscape. It is expression of eternity, of nothingness and death; a metaphysical dream." According to Paul Valery, "a look at the sea is a look at the possible."

I identify more closely with Valery's vision. Also, I appreciate the atmosphere aboard a research vessel, as did Henry Stommel of Woods Hole in the United States, the pioneer of Gulf Stream research, who wrote that "work at sea rubs off the sharp edges and makes us better people. The ship becomes a home away from home."

This statement implies many facets even of the ocean itself. The ocean is a good teacher which deals with many different people, with many disciplines, and with problems in space and time of very different dimensions. We have to measure ocean currents in meters per second, but the growth of deep-sea manganese nodules in millimeters per million years.

As a university professor I am a teacher, too. Therefore, I am grateful for a generally friendly "teacher ocean" and for the fact that it can be mastered by many excellent ship crews. I am grateful to all my exemplary teachers in science and to all friends and colleagues around the globe, including those in Japan, who are giving me advice. But a good professor should only be happy if he has students and collaborators who will surpass him in research. Looking around in Germany and abroad I feel really happy that many of my former students are surpassing me in research. I am especially grateful to them as well.

Finally, I would like to give thanks to the people at home, away from my home at sea, and first of all to my family.

In summary, I have tried to demonstrate some relationships between the seafloor and the environment from the coast to the deep sea and from the present to the past and possibly to the future. But I had to select only very few mosaic stones from my own work and the work of the Kiel team. These stones must represent reliable results. Only then can you use these stones to put together at least the design of the whole mosaic. I suppose that the Blue Planet Prize was given to me because I have always stressed the importance of careful and reliable investigations as a base for more general statements.

Of course, we all have to think globally, but just like in daily life we have to begin with regional or even with local actions and investigations. The ocean, however, where everything reacts with everything and where there are no real boundaries, offers better opportunities to think globally than do the continents. What a challenge to unveil the secrets of the sea and what a chance to use some of the results and apply them to urgent problems of present and even future global, regional, and local environments. Thank you very much.

(Slides are mostly taken from E. Seibold and W. H. Berger, *The Sea Floor,* 2nd Edition; Springer Verlag, Berlin, Heidelberg etc., 1993; and from photographs by the author.)

Follow-Up Discussion

Introductory Comment

Thank you very much, Professor Seibold. Won't you please take a seat. Now we would like to start the discussion between Professor Seibold and Professor Murakami of the University of Tokyo. Professor Murakami is now serving as the director of the University of Tokyo's Research Center for Advanced Science and Technology. He has studied the history and philosophy of science for many years, and in recent years he has written many books and articles on the global environment.

MURAKAMI: Thank you very much for the introduction. As you know, Professor Seibold was born in Germany and he speaks very good English. Obviously, he gave his lecture in a language that is not his mother tongue. To return the courtesy, I also feel that I need to speak a language that is not my mother tongue. The organizer of this meeting has actually requested me to speak in English in this discussion, even though my English is not so good. But I would like to do my best to have this discussion with Professor Seibold in English, so please allow me to speak in poor English.

Professor Seibold, I would like to express my wholehearted congratulations on your being awarded the Blue Planet Prize in recognition of your celebrated works of marine geology. I was introduced as a historian or a philosopher of science and technology, which means that my background is quite different from yours and that I am almost a layman in your field of marine geology. So I am not qualified to talk about what you have discussed in your lecture. So let me speak a bit more generally on more general subjects.

First, I would like to ask you a question. Recently, of course, the awareness of environmental problems is increasing worldwide. This Blue Planet Prize itself symbolizes the growing awareness of environmental problems. When you started your academic career as a marine geologist, did you anticipate this sort of boom of interest in environmental problems? Did you have any awareness of the linkage of your subject with environmental problems?

SEIBOLD: Thank you. To be honest, I have to confess that this was not the case. I was a geologist in southern Germany, and I was studying limestones of Jurassic times, some 150 million years ago. But to study these limestones, I was eager to know how they originated. And because they contained marine fossils of animals living in the sea in former times, I had to go to the sea for an opportunity to study where today limestones are formed. And therefore I went to the Bahamas first. And then we had the first cruise of *Meteor*, which went to the Persian Gulf to study the origin of limestones. I learned quite a lot, because I thought formerly that limestone was a precipitation of $CaCO_3$ directly from the seawater. And I thought even that I could prove in the Bahamas that sometimes this is possible. I was wrong. And I learned in the Persian Gulf that limestones are parts of organic shells, of $CaCO_3$ shells. Owing to the grinding of the waves and the currents and other animals, these get smaller and smaller, and finally they turn to limestone. Fine. I investigated the environment, but only to understand the marine environment some 150 million years ago. And only after a while, beginning with the Bahamas, where precipitation is linked to the exchange of CO_2, it was the beginning for me to understand that CO_2 is an important gas for our environment, too.

MURAKAMI: Thank you. Next, what I would like to ask concerns the special characteristics of environmental problems. The study of environmental problems requires a vast variety of knowledge and disciplines. Of course, marine geology is an important constituent of the knowledge of environmental problems. But let us consider the natural sciences only. Many fields of Earth sciences, such as climatology or botanical sciences or chemistry or even physics—all these disciplines and related technologies, such as monitoring technologies and devices and so on, are I think indispensable for environmental studies. Also, take the example of CO_2. The recent dramatic increase of CO_2 in the atmosphere may be caused not only by natural reasons, but also by human activities, just as your first slide showed. That means that even the problem of CO_2 itself involves human activities. So the approaches to

environmental problems almost necessarily require the integration of the knowledge of almost all kinds of disciplines, not only the natural sciences but also the social sciences and humanities. This specific feature of environmental problems you are now dealing with. And as a marine geologist, sometimes this specific feature perhaps discourages you from tackling this problem, because it is too vast and broad for a single person. Could you please respond to these comments?

SEIBOLD: You touch on a serious problem, because to some degree there is no environmental science. To some degree, this is a mosaic and we have to put together mosaic stones. As you mentioned, we need geologists. Geologists should be well educated to cover different fields. I, at least, had to study botany, zoology, organic and inorganic chemistry, geology, and mineralogy, of course. Therefore, the background in former times, at least, was very solid. At least we could speak with a chemist and a biologist, because we knew the field a bit. But more and more, science is specializing, even in geology. That is a very big danger. But if you are really interested in science, you have to decide after a while to be a specialist in marine geology, in inorganic chemistry, or in something like that. And maybe after a while, when you have proved that you are able to do research in depth, then maybe you can come to a level where you can look over the fence and compare your results with others.

There are very few geniuses. They can really think in an interdisciplinary way. In Germany, I know Professor Eigen, a Nobel Prize winner, who is a mathematician, a biologist, and a chemist altogether. He can speak with everybody involved in these specialties. But that is something only very few people can achieve.

But what about the rest? I guess you should prove first that you are a good chemist, or that you are a good hydrologist or geologist, and then go on and make general statements. As I said in my lecture, one should base everything on reliable, sober research and not fall into the danger of some superficial environmental studies with many general statements high up in the sky but with no touch with the bottom. I guess that is dangerous. But how do we encourage young people gifted enough to be more than specialists and to look over the fence? And of course I include social sciences, even political sciences. Some of the problems I touched upon cannot be solved without changing our habits, our lifestyle. A geologist cannot convince everyone to change something like lifestyle. I guess this is a very difficult task for other sciences, assuming sciences can help at all. Therefore, my advice would be to begin with one specialty, but to do it carefully and correctly, and then go on and look over the fence.

MURAKAMI: Thank you. Your advice is, then, to first be a specialist and second to be interested in general matters. But we are not always a genius like Dr. Eigen, so it is quite a difficult task for us. Is there any magic to accomplish that difficult task?

SEIBOLD: Of course, I know some very respected colleagues who tell me that we have first to be environmentalists widely looking over the horizon. "It does not matter whether my assistant is a chemist, biologist, or geologist; he or she should have a broad horizon and then everything will be okay." That is another approach. Let us see what will be more successful in the long term.

MURAKAMI: The next question is from a slightly different perspective. I understand you have already visited Japan many times, and you have very good colleagues and collaborators in your field here in Japan. And also you have a rather good knowledge of Japanese culture, on the whole. But you have grown up in a Western culture. Based on your abundant experiences in the West and the East, have you ever found any differences between people's attitudes toward nature in the West and the East? This is a quite broad question.

SEIBOLD: I feel like a Ph.D. candidate with the faculty members sitting around to test my ability to look over the fence. I feel that this is a very difficult question. We have no time to go into details. Roughly speaking, I think that Western European culture was very successful in developing natural sciences during the last, let us say, 300 years. But this was an intellectual approach to nature. However, the intellect is only one part of human beings, and

therefore I feel that the Western approach to nature stressed perhaps too much the intellectual part of the idea of nature around us. There were a lot of successes. As the president of the European Science Foundation I always complained that there were a lot of too narrow historical papers and books in the different nations. Italians are studying Galileo, the British are studying Newton, we are studying Leibniz, and the French are studying Descartes. But nobody was studying the European approach to the history of natural sciences. Modern natural sciences were born in Western Europe. Therefore, I always tried to raise funds to do more in historical studies, because as I explained it to many people in Western Europe, this is our baby. Modern natural science is our baby, and good parents should feel responsible to their children. They should be proud that science was so successful, but they should take care of the evolution of the child. And I feel that we are in a situation where we should be responsible for what the baby is doing, even though it is grown up now.

I am not a specialist in the history of science, but I feel that this evolution of the intellectual approach to nature came to Japan roughly some 100 years ago, about three generations back, and we have more than 10 generations back. Therefore, I hope that Japanese are nearer to the whole nature, because they are separated from nature only by 100 years of the intellectual approach to nature. But you should tell me whether this is true, that the Japanese are nearer to nature because they are not separated by this 300 years of an intellectual approach.

MURAKAMI: One thing is that the natural sciences must be based on, to some extent, some feeling of distance between man and nature. Is that what you are saying?

SEIBOLD: Yes. I closed my lecture by saying that you cannot go aboard without emotion if you are a really successful marine geologist. But of course, when you are a biologist you have your microscope and your small animal, and you do have distance. You must consider it as an object and not as a subject. It is an object to be studied. You cut it and everything like that, and this is of course to some degree a distant approach to nature. But you see, you can be a literature professor—and now I am looking over the fence—and you study a wonderful poem of Goethe or someone else, and you know everything about the commas and so on, but you should not forget to admire the beauty of the poem. And it is the same thing when you are a geologist looking at the landscape here in Japan and you can explain everything about Mount Fuji, for instance, but when you forget about the beauty of the view, then you are not a real natural scientist, in my opinion.

MURAKAMI: But still the natural sciences require a kind of objective standpoint to nature. Keeping the distance between the subject and the object.

SEIBOLD: Yes.

MURAKAMI: Do you think that kind of attitude, I mean the natural scientific attitude toward nature, has some influence on the way one tackles environmental problems? For instance, as you said, I also believe that the Japanese have, compared to Western cultures, a closeness to nature, a more intimate feeling for nature. Yes, that is true. But as you may know, almost from the very beginning of our modernization we had a very bad experience with pollution, such as copper-mining pollution of soil and atmosphere. This was a terrible experience. And also after WWII, we had the Minamata disease and many other disastrous events caused by pollution of the seas, soil, water, atmosphere, and so on. It means we failed to prevent the disastrous pollution of modernization. The close attitude toward nature does not necessarily mean that we are always aware of environmental problems. Rather, we place too much trust in the natural power of nature for cleaning the atmosphere and water. Maybe we have over trusted nature or the power of nature, because we are too close to nature.

SEIBOLD: That is extremely interesting to me, because I thought that, like the dragon on some of your old buildings with two faces—a friendly face and a frightful face—so was nature in Japan. I always thought you were much

nearer to the dangers of nature. In Germany we have a strong earthquake every 500 years. We have hopefully no volcanic eruptions. But you are always, day and night, threatened by earthquakes, volcanic eruptions, tsunami, and typhoons, and therefore I am very astonished that you say you have a friendly feeling for nature. Because you are living always under the threat of nature. How can you keep your trust with this experience? I would say that in Western Europe, a religious man will say that god will help us. But I think this is not sufficient. And for you to say that nature will help us is too easy.

MURAKAMI: Yes. I guess that instead of believing that god will help us, we believe that nature helps us?

SEIBOLD: Yes?

MURAKAMI: And we leave the things as nature does or as nature goes, so to speak, instead of controlling her. We do not have a will to control nature, but just leave her as she goes.

SEIBOLD: That is a very interesting remark about the control of nature, because an English philosopher about 400 years ago, Francis Bacon, said that we wish to control nature. But he was very wise, and he said to control nature you must first obey nature. For me as a scientist, you must first understand nature—her laws and processes—and then you can obey when you understand. But you are right. The principle is perhaps coming from the Bible. In the Bible, nature is second to people. And people exploit nature. Maybe this is a big difference between Japanese thinking and Christian thinking.

MURAKAMI: Again, I would like to add one thing. The specific attitude toward nature in the West is not always unfavorable for environmental problems. And similarly, the Japanese attitude toward nature is not necessarily favorable to solving environmental problems.

SEIBOLD: It could be a European approach to the problems of the environment, that we have even to improve nature with molecular biology, and so on. Of course, there are a lot of colleagues who believe that we can improve, or already have improved, at least some features of nature. This would be the positive Western European attitude. But to come back to your first remark, I guess young people—and I know, because I like to have students around me—perhaps are swinging back like a pendulum. You know that the Green Party has entered our parliament again, and in this party there are a lot of idealists. And they feel that the approach to nature and environmental problems was too materialistic and cool and objective and that we should change it. I am very glad that these problems were raised by this party, and of course by many other people. But again, I would like to stress that we should begin discussions only when we have clear facts and when there is an objective background, if this is possible. We should not forget that idealism and emotion and fine sentiments alone will not help us too much. Only with good chemistry can we fight chemical pollution.

MURAKAMI: You referred to the young people, and I am rather pleased to hear that in your country at least some part of the young generation is interested in environmental problems. Not only interested in, but participating in movements for improving environmental problems. Of course, here in Japan also we have the same phenomenon, but at the same time we are suffering from, or maybe I should say that many people tell me that we are suffering from, the growing indifference to natural science and engineering among the young people. Or they are beginning to lose their interest and concern in natural sciences and engineering. This is partly because, as you know, the very competitive entrance exam system to the universities discourages them, because natural sciences require many subjects of study. When the students enter university in the social sciences or humanities departments, they are freer and have more time to enjoy traveling and dating. But the students in the natural sciences department are required to do much work. So they have a rather hard time in the universities. And after graduating from university, they are not

sufficiently rewarded for relatively heavy duties, at least economically speaking. I think that kind of phenomenon can be found in many advanced countries, but especially in Japan we perhaps are suffering from that kind of indifference toward the natural sciences among young people. What do you think of this? What about the German situation?

SEIBOLD: I have no special experience with this. But your complaint, that more and more young students are more interested in going into economical sciences or becoming a lawyer or something like that—I hear the same complaints from America. More and more students there are leaving natural sciences. Now there may be several reasons. I guess natural sciences get more and more complicated. And normally a chemistry student in Germany has, together with medical students, the longest period of study, because he has to work very carefully in the lab and has to learn a lot of methods and so on. And geologists, too. They have to go abroad, to the field, and study the rocks. When you are in a tropical country or the Sahara, it is not the easiest way to do research. It is easier to sit at a comfortable table and to be an economist, of course. Therefore, first of all the curiosity of what one will do with a life is important. Is my first priority to do research, am I curious to find out something? If so, I do it. Or—and this happens in America and more and more in Germany, too—the money is important. What do I earn? I do not know what the situation is here. We are sponsored here by a chemical company. For me, it is very interesting that during the time when I had to cooperate with big chemical companies in my position in Bonn, all the top management people of the three big chemical companies in Germany were chemists. Nobody is a chemist any longer. A lawyer, economist, financial specialist, and so on. You see, it is even creeping into such an industry where you think that the spirit of the company depends on the boss. And when the boss is a commercial man, it is another atmosphere, another climate for science. I am not a specialist, and you can correct me. But the good news is that we always have young, gifted, enthusiastic students, and they do biology and geology, and they do it even when they do not earn money. They are really full of enthusiasm, and these are the people we need, and not the people who are asking how many yen they get per month when they are 65 years old. This type I do not like.

MURAKAMI: I am very pleased to hear that. But with regard to what you have just said, scientific activities should be driven by the curiosity or the pursuit of truth of individual scientists. I believe that. But at the same time, recently the character and the features of scientific activity are, to me, changing. They are changing from curiosity-driven enterprise to the mission-oriented or goal-oriented enterprise. The scientific activities are almost always directed to the mission goal, and each scientist plays a role similar to that of a blue-collar worker on an assembly line. They are driven by the mission, I am afraid, and there remains very little room for individual curiosity-driven enterprises. What do you think of this?

SEIBOLD: That is true. I am fighting even here to promote fundamental science, where the question is whether one is driven by curiosity or by profit. It is not negative to be driven by profit. Of course, a company has to be driven by profit, not by curiosity. But you mentioned another aspect. Because we believe, at least, that only science can solve a lot of fundamental problems of health or of the environment, science gets more and more important in these respects. Even politicians feel after a while that science is worthwhile to deal with. That is a big success, but it is a big danger, too. Because they think that science can solve their problems, and more and more the government comes to us and gives us money, more or less, and we are supposed to give some answers. The mission-driven or problem-oriented science gets more and more importance, and that is fine. In industry, at least the bigger companies should allow some researchers, some brilliant researchers, to be completely free to do what they will. I know some American oil companies that let excellent researchers among a big staff do what they want to do. They receive everything, assistance, money, travel, everything they want to have. The company feels that if a researcher's quality is excitingly good, after a while, maybe even after five or ten years, the results originating in curiosity come back as a profit to the company.

Therefore, and maybe now I am being rather Buddhist by offering the positive and the negative sides of the issues—you should have both things. We are responsible for a lot of money that the governments, and therefore the taxpayers, are giving us as scientists. When there are some governmental approaches and governmental wishes, you should do something about cancer or other urgent social problems. But do not forget that real progress in science is not coming from problem-oriented science, but it is coming from other fields. Maybe a chemist or a mathematician someday will solve big problems in cancer research. And therefore, one should have both things: project-driven science and free research, but only for the top people and not for those who claim free science but who do second-class research.

MURAKAMI: Thank you very much, Professor Seibold. I am requested to keep the time for the open discussion on the floor. So I would like to ask the audience now to respond to the discussions. Please do not hesitate to ask any questions.

QUESTION: Thank you very much for your lecture. It was very interesting. And I would like to congratulate you on winning this award. I am not a scientist, so maybe I am not entitled to ask a question, and I needed a lot of courage. But I do have a burning question to ask Professor Seibold. Desertification and deforestation—these problems are occurring. And I feel very much threatened by those problems. Your deep-sea research and continental shelf research looks at places we usually cannot see, so from the environmental point of view, how serious is the threat in the ocean right now? I am very interested in your response to this question.

SEIBOLD: The threat given by anthropogenic pollution, or another type of threat? You think that pollution is a threat to the ocean?

QUESTION: Yes, that is right. For example, the atmosphere has pollution that we can actually see with our eyes, but I understand there are a lot of threats in the ocean. Experts have that type of information. For example, you said that millions of years was the dimension for the geologist, but in the short term or long term I wonder if the threat of pollution is really occurring in the ocean, and how would that affect the environmental issues on the Earth? So this is rather a simple question.

SEIBOLD: This is a very complicated question. Pollution can come from the atmosphere. And you can think that additional CO_2, to some degree, is a pollutant. Because I guess about half of the CO_2 released into the atmosphere is "eaten" by the ocean. But, though it can eat a lot, even the ocean has to stop eating eventually, and therefore this can be dangerous. At the moment, the ocean is very nice and eats half of the CO_2 and maybe for a long time can eat more. Fine. Pollution from the continents, from rivers or wind, contains a lot of dangerous materials like lead and cadmium and so on. And also radioactive substances leaving nuclear plants can go to the ocean, and this is pollution, too. Up to now, despite what Cousteau is warning, we are OK. He says that we are really disturbing the balance in the ocean and that it is dangerous. But you see, the ocean has a very friendly character because it has so many bacteria which eat a lot of these dangerous substances. The problem is not that we should put nothing in the ocean, because the ocean has a natural capacity to get rid of these things, a lot of methods to cope with these substances. But the problem is how much we can put in.

I was organizing a conference in Berlin where we invited top specialists all around the world about these questions. What can the ocean eat? With the ocean we were very optimistic. There are many possibilities. But the top danger comes from enclosed seas. The Baltic is extremely endangered, as is the Mediterranean, for reasons I tried to explain. Therefore, it depends what you are looking at. I would guess that the Japan Sea has a lot of problems and that we should do much more research there. This would be a model of a nearly adjacent sea with pollution and so on occurring.

But there is another type of danger for the deep sea when you stir up the deep-sea sediments. What are the consequences of this? As you know in Japan better than in Germany, you have a lot of precious metals on the

bottom of the deep sea, especially in the Pacific, where you have these so-called manganese nodules, polymetallic nodules, as the French say. And of course in due time they will become exploited. The problem is that when you stir up the bottom of the deep sea, you may damage the deep-sea animals living there under miserable conditions. Therefore, we may kill a lot of species when we exploit the manganese nodules. There are other problems with the deep sea, too. But you cannot compare the severity of these problems with the problems in ocean-adjacent seas.

QUESTION: Professor Seibold and Professor Murakami, listening to your discussion and presentation I finally came to understand the philosophy of Professor Seibold. Thank you very much. I would like to give some of my impressions after listening to your lecture and discussion. Since 1951, I have been involved in the prevention of pollution in the Tokyo area, so I have been involved in this kind of activity for more than 40 years. It was very difficult for me to understand during the lecture, but during the discussion with Professor Murakami I was able to understand the philosophy of Professor Seibold. So I am quite happy that there was a follow-up discussion. I would like to thank you very much for giving us this opportunity to hear your thoughts. We have to have facts before discussing problems. First, then, is scientific reality. I was happy to hear the same opinion from Dr. Seibold. Thank you very much.

SEIBOLD: You mentioned Minamata and other catastrophes. But you see, as in normal human life one learns from mistakes, not from successes. To learn from mistakes is really serious, and I admire the Japanese quick response to mistakes you have made. After a while, you think nature will help. Fine. But if it does not help, you finally get down to action. And for me an incredible example is a harbor on Kyushu. The bay was completely polluted. Even the sea bottom was nearly poison. What did they do? They dredged out all the bay and got rid of this stuff. There were no fish in this area, no animals could live decently. But now the fish have come back. And this is for me a wonderful example that after you discover that the situation is dramatic, in Japan you have long discussions and then do something. And therefore I am very glad to hear that you have the wonderful duty to fight against pollution in the huge Tokyo area. It is a very rewarding profession to help fight pollution.

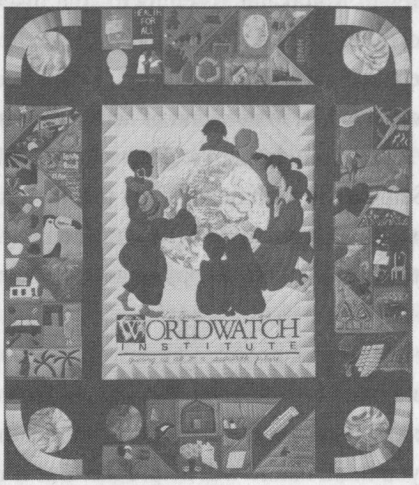
QUESTION: This is a simple question, I think. In Japan, there have been efforts to liquefy CO_2 that comes out of the power plant and to put it into the deep sea after liquefaction. So is the deep sea completely separate from the system that we live in, and if we take such a measure would that affect the environment of the ocean?

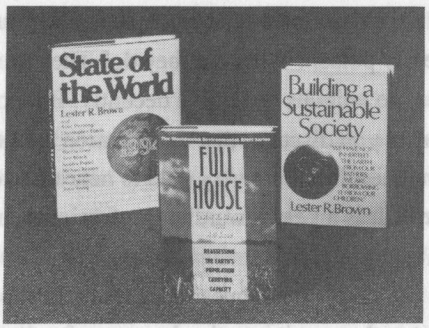
SEIBOLD: Two years ago I had a discussion with a Japanese industrialist. He told me that you would solve the CO_2 problem by getting rid of the CO_2. Of course, you can get rid of the CO_2 with a lot of energy, and this is part of the problem. You see, when you give the ocean the chance to dissolve $CaCO_3$, then you get rid of a lot of CO_2. And therefore, as long as there is $CaCO_3$, the whitish mud in the deep sea, it is a good reserve for further digestion of CO_2. But after you dissolve this white calcareous mud, then the rest of the mud, the red clay, comes out and covers it, and there will be a stop to the ongoing dissolution of $CaCO_3$ and the consumption of CO_2. Therefore, it is risky to promise anything. We should not forget that there are a lot of these proposals, but the technical ability to pump down into the oceans huge amounts of gas and so on is practically unfeasible. Another approach is to produce more plankton by adding iron, which is important for organisms. You can improve and increase the productivity of surface-water organisms, and they consume CO_2, and they send the CO_2 in organic remains down to the deep-sea bottom. So you get rid of CO_2 in the atmosphere. Good idea. But you see that just the technical aspect is so extremely difficult and expensive. The first big experience in the Pacific of some American colleagues was very disappointing. Therefore, I am very skeptical about whether we can get rid of the CO_2 by such tricks.

MURAKAMI: I am sure there are more questions, but we are running late. We would like to conclude the first part of this lecture program with Professor Seibold. I would like to thank the audience for participating enthusiastically. And thank you, Professor Seibold, for your very kind cooperation.

Part Two

Development and Implementation Award Winner's Lecture and Follow-Up Discussion





"Environmental Revolution"

Lester R. Brown
Founder and president of the Worldwatch Institute

As the countries of the world were preparing for the UN Conference on Population and Development in Cairo in the early months of this year, one of the questions that was asked frequently concerned how many people the Earth can support. What is the Earth's carrying capacity? In order to answer that question, of course one has to consider other questions, because it's not only how many people that matters, but also their standard of living and consumption levels.

There are many ways in which the growth in human population could be constrained. One could be continually worsening pollution, for example, until it reaches the point where it affects the prospects for human survival, where it affects human health very directly. This is already the case, for example, in the former Soviet Union. More than a year ago, the Institute of Medicine at the Russian Academy of Sciences released its first report on the state of the health of the Russian people. That report said that for the first time in modern history, life expectancy in Russia was declining. It said that 11% of the children born in the last year had birth defects. It said that 55% of school-aged children had special health problems, that is, problems beyond the normal childhood diseases. Professor Vladimir Prokovsky, who was the head of the Institute of Medicine and the senior author of that report, said that even if all pollution stopped immediately in Russia, they would face deteriorating health conditions for at least the next 25 years. He said that 10% of the food supply was chemically contaminated and 50% of the drinking water in Russia was chemically contaminated. He said the industrial progress of the past 30 years has been bought with the health of the Russian people. And he said that they will be paying that cost for at least another generation.

I cite this as an example of one country that has experienced a reversal in its health conditions as a result of pollution, both chemical and radioactive. But as we look at the world, we do not, even in severe conditions such as those in Russia, see pollution emerging as the principal constraint on the number of people that the Earth can support. Could it be water scarcity that will eventually limit the number of people? I suppose given this past summer here in Japan and particularly in Tokyo, when water was being imported by ship from abroad, the idea that water could become a principal constraint on future population growth might be a bit more plausible than it was before this year. But we don't think that water is going to be an immediate constraint on the growth of world population, in part because most of the water we use is used to produce food. Of all the water that we withdraw from underground aquifers and from rivers and other surface sources, two-thirds is used for irrigation. The other one-third is used for residential purposes, industrial purposes, etc.

We think the principal constraint on the growth of world population is going to be the food supply. Now this is not a novel idea. As you know, Thomas Malthus presented this idea two centuries ago, so I don't take credit for it. But I do want to say that I think we are moving into a period where the idea that food supply will not increase as fast as population is acquiring a reality that it has not had except for brief periods during the two centuries since Malthus wrote his now famous book.

In looking at the food prospect, we see the emergence of three physical constraints on efforts to expand the world food supply: the limits of oceanic fisheries to supply fish, the limited amount of fresh water that is available, and—and this is one that people do not think very much about—the physiological capacity of crop varieties—rice, wheat, and corn—to use fertilizer. This is also a limit, a natural limit.

Let me talk about each of these briefly. With seafood, we have all lived during a period when the world seafood catch has increased enormously. Between 1950 and 1989, the world fish catch increased more than four

times, 4.6 times to be exact, going from 22 million tons in 1950 to 100 million tons in 1989. It was a remarkable period. The average person in the world in 1989 consumed 19 kilograms of seafood, compared with nine kilograms per person in 1950. So the average person in the world doubled seafood consumption from 1950 to 1989. And then suddenly we hit the wall, so to speak. And the seafood catch has not increased at all over the last five years; in fact, it has declined slightly from the 100 million tons in 1989 to between 97 and 99 million tons in the years since then. Because the total fish catch is no longer increasing, the per capita seafood catch is declining as a result of population growth.

The marine biologists at the Food and Agricultural Organization in Rome report that all 17 oceanic fisheries are now being fished at or beyond capacity, and that nine are in a state of decline. Some of them, I might add, are actually collapsing. The cod and haddock fishery off the Canadian coast of Newfoundland has literally collapsed. We read a few days ago that the New England fisheries for cod and haddock may also be closed by the U.S. government in an effort to salvage them.

I've just been talking to the vice president of the UN University in his office upstairs about what's happening to the seafood catch. What will the economic consequences be of a declining seafood catch per person as far as we can look into the future? One of the consequences is rising seafood prices. Thirty years ago people who could not afford meat ate seafood. Certainly, that was the case in the United States. That's no longer true. If you go into a fresh seafood shop in Washington, D.C., or New York, you don't see any poor people there. The prices are too high. So we're seeing a change in the price of an important food product that much of humanity depends on. I would point out that the world fish catch, at 100 million tons, is equal to the world's production of beef and poultry combined. Now that will not surprise most of you in Japan because of the extraordinary levels of seafood consumption in this country. But in other parts of the world, the idea that the seafood catch equals the production of beef and poultry does come as something of a surprise.

So we are pushing against the limits of the oceanic fisheries at a time when population is 5.6 billion. But we're adding 90 million a year, which means that each year you and I as average citizens of the planet will have less seafood than we had the year before. What are the consequences of that economically, socially, nutritionally, politically? No one knows, because no one has been analyzing this issue and looking at it with an eye to the future—a big gap in the global research agenda.

We could talk about water. Water is becoming scarce in many parts of the world. In the United States, we see water scarcity throughout the Southwest, in the states of California, Arizona, Nevada, New Mexico, and Colorado. We see water becoming increasingly scarce in the southern Great Plains of the United States, one of the world's major wheat-growing regions. In the southwestern United States, nearly all the water has now been claimed, whether it's water from, say, the Colorado River, or whether it's underground water supplies. Overpumping is now widespread in this region of the country. When the demand for water in cities increases, they can satisfy it only by taking water away from agriculture, by buying the irrigation rights from farmers. Los Angeles, to get the water it needs, must now get it by taking it away from agriculture.

I have family in ranching in northern Colorado, about 70 miles north of Denver and east of Fort Collins, if you know U.S. geography at all. And in that county, a couple of years ago an agent came in and began buying irrigation water rights from farmers and ranchers, and eventually bought the irrigation rights from a few hundred farmers. He was offering a price that no one could resist, but no one knew who he was buying the water for until he had bought all the rights, and then it was revealed that he was buying the water for a small city near Denver called Thornton, Colorado. They planned to build a 60-mile pipeline and take that water to Thornton to satisfy the needs of this growing city toward the end of this century and in the early 21st century.

That example has been repeated over and over again around the world. In Beijing, which is not a small city, the irrigation reservoirs around that city were once used by both farmers and the city. Recently, farmers were banned. They no longer have access to those reservoirs in the agricultural region surrounding Beijing. They must now either go back to dryland farming, or they must drill wells and pursue the falling water table downward.

To finish with the United States, the Department of Agriculture reports that 21% of all irrigated land in the United States is now being watered by drawing down underground water supplies, by overpumping. In the southern Great Plains of the United States, this is the result of relying on a fossil aquifer, an aquifer that was formed a long time ago in geological time, and which is not today being recharged in any significant way. And so as it drops, eventually farmers have to go back to dryland farming.

In China, a substantial share of the irrigated land is being irrigated by drawing down underground water tables, also. Almost all of northern China is now a water-deficit region, that is, it is using more water than nature makes available. And it is a water-deficit region because it is drawing down the underground water table. One of the interesting geological questions, Professor Seibold, is what happens to a region like northern China when you keep depleting the underground water supplies. What happens to the geological structure, what happens to the aquifers, what happens to the recharge potential? It's an area, I think, that has not been researched in much depth, but even one who's not a geologist can imagine that there will be some lasting consequences.

These are some of the questions that we need to be asking and trying to answer as we try to respond to human needs for water that are growing far more than that which would be required to supply the needs of 90 million additional people each year. Because as incomes rise, people consume more water. What happens to the demand for water as 1.2 billion people in China begin to acquire indoor plumbing, showers and bathtubs, flush toilets, and running water in the kitchen? This may be one reason why 300 of the largest cities in China now are facing water scarcity, 100 of them severe water scarcity. And I have to conclude that in most cases, they will satisfy their future water needs, the deficits that are developing, by pulling water away from agriculture. There is no other place from which to obtain it. Before I leave China, one more point. As you probably know, because of an extreme shortage of water in Beijing, questions are being asked as to whether it should be the capital of China permanently, or whether the capital should be moved to the south, where there is at least adequate water supplies. Another alternative is to move water from southern China, which still has a surplus of water, to the Beijing region with a long canal. This would be roughly 900 miles. It would be as though Washington, D.C., decided to get its water from the Mississippi River, 900 miles to the west. This is a major civil engineering project that is in prospect for China to supply the water needs of Beijing and Tientsin.

In India, water tables are now falling in several states because of overpumping. One of the advances associated with the green revolution over the last few decades has been an increase in the double cropping of wheat and rice. Throughout central and northern India, many farmers grow two grain crops a year: they grow winter wheat, and in the summertime they grow rice. Both crops are irrigated because the wheat is grown during the dry season. And they have greatly increased their production. I helped draft 25 years ago the agricultural plan for India, which led to a doubling of its wheat harvest in seven years, a phenomenal advance. Today, India is facing growing water scarcity and the prospect of cutting back on the amount of double cropping of wheat and rice because there is simply not enough water.

So water is emerging as a constraint on food production. I could talk about other parts of the world, but I've chosen to talk about the United States, China, and India because these three countries are the world's three leading food producers; together they produce nearly half the world's grain.

If land is being irrigated by overpumping, by depleting the aquifer, then at some point when the aquifer is finally depleted the amount of irrigation must be reduced. For example, if the rate of irrigation pumping is double the rate of aquifer recharge, then when you finally hit the bottom you have to reduce the amount of pumping by half, and that means a very substantial cutback in food production. So we're facing some real adjustments ahead on the water front.

The third natural constraint that I mentioned, which has not gotten very much attention compared with water, for example, is the physiological limits of crop varieties to benefit from fertilizers. In 1847, a German scientist, Justus von Liebig, discovered that all the nutrients that plants take from the soil could be returned in mineral form. It was a major discovery. If there were a Blue Planet Prize then, Professor Seibold, he probably would have been the winner instead of you! Yes, he agrees. It was an exciting advance in our understanding of plant growth and nutrition

and physiology, but we did not really take advantage of that knowledge until nearly a century later. As recently as 1950, the world was using maybe 14 million tons of fertilizers. By 1989, it had reached 140 million tons, a tenfold increase. It was the growing use of fertilizer that was the engine driving the growth in world food output over the last four decades. It was fertilizer more than anything else that permitted the farmers on the land in 1950 to double their production within a generation. No generation of farmers in history had ever done that before, but the world's farmers as a group between 1950 and 1980 doubled their harvest and they are still increasing it.

Many of the things that we have done to increase food production over the last four decades have really been designed to increase the use of fertilizer. The reason we irrigate is so that we can use more fertilizer and increase yields. The exciting thing about the dwarf wheats and rices—and that breakthrough came in this country a century ago—is that they can use much more fertilizer than the traditional varieties, the traditional tall, thin straw varieties of wheat and rice. One could easily triple the amount of fertilizer effectively used and increase the yield accordingly.

But since 1989, world fertilizer use has actually declined. In part, that's for agronomic reasons, because in many countries using more fertilizer no longer increases production. So production has leveled off. Farmers in the United States in the early '90s are using less fertilizer than they did in the early '80s, because using more fertilizer doesn't have much effect on output. We could double fertilizer use in the United States next year, and you probably could not see it in the production trend. It would be as though you and I decided that instead of eating three meals a day, which most of us do, we would eat six meals a day. It probably would not increase our productivity very much; in fact, it might diminish it somewhat. Plants are living beings, too, and once you reach the limit of what they can do physiologically, then giving them more fertilizer doesn't have much effect. If you and I were getting only one meal a day and we suddenly were given two meals a day, then we would become much more productive. And that's the way it was with crop varieties and fertilizers throughout most of the last four decades. But suddenly we've reached the point where more fertilizer has little use. Fertilizer use in Western Europe, Japan, and the United States today is no more than it was a decade ago; the trend is basically flat. So that engine which has been driving the growth in food production no longer works very well.

If we can't use more fertilizer, if we can't keep greatly increasing fertilizer use to boost food production, where will the gains come from? How will we feed 90 million more people each year? And the answer is, no one knows.

In talking just a bit ago with the vice president of the UN University, we were discussing the environment and the economy, and the environment and food production. I'm not going to spend more than a few minutes discussing this, but I would point out that soil erosion is now a serious threat to the growth in food production in many parts of the world. It is especially a problem in developing countries. One can hike around the highlands of Ethiopia today and see abandoned villages that 10 or 20 years ago were productive. The reason they have been abandoned is because there's not enough topsoil left to support even a subsistence level agriculture, much less a market surplus producing agriculture. The same is true in many of the Andean countries of Latin America, for example. It's true for parts of Indonesia. I could go on and on. Soil erosion is slowly undermining the long-term food prospects on probably 30% of the world's cropland.

Another question is global warming. This summer was a very hot summer in Japan that affected rates of water evaporation. But a very hot summer, if it got much hotter, would also affect rice pollination. If temperatures get too high, rice will not pollinate. Neither will corn, for example. In the United States, in the summer of 1988, when we had record heat and drought, our grain harvest in that year dropped below domestic grain consumption for the first time in our history. We didn't think it was possible, at least I did not think it was possible, that the breadbasket of the world would suddenly find itself not producing enough to satisfy even its own needs. Fortunately, at that time we had enormous reserves. We typically produce about 300 million tons of grain, we use 200 million tons domestically, mostly for livestock feeding, and then we export 100 million tons to something like 100 countries around the world, the largest of which is Japan. Now fortunately that year we had enormous reserves, and so in effect we exported those reserves to satisfy export commitments, again including to Japan. But reserves were drawn down, and they have never been rebuilt. If we had another summer like the summer of 1988, then we

would not be able to satisfy export commitments, and then suddenly there would be intense competition among importing countries for inadequate exportable supplies of grain. Prices would double or maybe triple almost overnight, creating instability in the world economy.

In looking at the long-term human prospects and in thinking about the various things that can constrain future progress and destabilize the future both economically and politically, I think it's food that we have to worry about. And the question is, what will happen to bring the food issue into sharp focus? I mentioned the possibility of another summer in the United States like the summer of 1988. That's a possibility, and that would be the wake-up call.

Another possibility, and I think of this as more of a reality, is China's emergence as a massive food importer. We have in East Asia a situation that is unique in that we have countries that are already densely populated before serious industrialization begins. Japan is such a country. When Japan's rapid industrialization and movement toward a modern consumer economy began in the 1950s and accelerated in the '60s and '70s, we had a country where a lot of cropland was used for industrialization purposes. So much agricultural land was lost to nonfarm uses—building factories, warehouses, highways, etc.—that grain production actually declined in absolute terms. Grain production this year, which is a good harvest year, as you know, is probably close to 40% less than it was in 1960, or at least something on that order of magnitude. And this is simply because the amount of land loss has outstripped the increase in land productivity. A similar situation exists in South Korea and in Taiwan for the same reasons. The process started there maybe 10 or 15 years after it did in Japan.

As we look at China, we see exactly the same situation: a country that is already densely populated before it moves into the era of rapid industrialization and the establishment of a modern consumer economy. And so what we're looking at in China is the prospect of very substantial losses of cropland over the next few decades, losses so large that they will override the rise in land productivity, leading to an absolute decline in grain production, as has happened in Japan, South Korea, and Taiwan. Japan last year imported 73% of its total grain supplies; although it was almost self-sufficient in rice, it imported all feed grains for livestock and most of the wheat consumed.

It is one thing when a country of 120 million imports 77% of its grain. It is another thing when a country of 1.2 billion people begins moving in the same direction, and that's what we're faced with in China. Unfortunately, most of the analysts of world agricultural supply and demand trends have overlooked this point. They have assumed that China's food production will keep increasing steadily as far as we can see into the future. I don't think that is at all likely. By an accident of history, China is beginning to expand its demand for food at a phenomenal rate at a time when the world is beginning to press against some of the natural limits to the growth in food production. I mentioned the seafood catch, for example. In an earlier period when population pressure built on the land in Japan, you turned to the oceans for your animal protein on a large scale, and this was very successful. The fish and rice diet of Japan began to evolve. That option doesn't exist for China, of course.

So we have the constraint on seafood supplies, we have the constraint on water supplies, and we have the limits on the amount of fertilizer that available crop varieties can use. So we have some constraints emerging just at the time when China is getting ready to move into the world market to import massive amounts of grain. Exactly when that will come we don't know. It could be before the next harvest, because as you may know grain prices in the 35 largest cities in China in August of this year were up 60.2% above August of last year. And this was during the harvest period. We don't know what will happen in the winter months as we look ahead to next year's harvest. We also know that the government in Beijing cancelled trading in rice futures on the Shanghai Commodity Market a week ago Friday because they thought there was too much speculation in the market. But it's another manifestation of the degree of scarcity that exists in China.

We know that population growth in China will increase the demand for food, even though it's increasing very slowly by international standards, certainly by third world standards—a bit over 1% a year. But with such a large population base, this still means China will add 490 million people between 1990 and 2030. That's the population of the United States and two Japans plus. But in addition to population growth, the more important source of growth in demand for food in China today is rising incomes. What we suddenly have for the first time in history is 1.2 billion people trying to move up the food chain at a very rapid rate. When the United States was in a similar period of

development some decades back, there were 200 million Americans. For Europe, it was 320 million, and for Japan it was 100 million. We're now looking at 1.2 billion people trying to do that, and doing it at a rate that is almost without precedent. Listen to these three numbers: 13%, 13%, 11%. Those are the rates of economic growth in China in 1992, 1993, and estimated for 1994. A phenomenal rate of growth for 1.2 billion people. Some of course are going up faster than that and some less, but on average this is a phenomenal advance.

So you begin to wonder what this means in terms of the demand for livestock products and therefore for grain. In China, there's no rangeland left to be developed. They can't turn to oceans in a major way for livestock products, so they can only get more livestock products or fish by feeding, basically grain.

Whenever you multiply anything by 1.2 billion, it's a lot. One more bottle of beer for each adult in China requires 370,000 tons of grain. In 1990, the average person in China was consuming 100 eggs per year. The official goal is to raise that to 200 eggs per person annually by the year 2000. Two hundred eggs per person, and by that time there'll be 1.3 billion people. That's 260 billion eggs. Getting from 100 eggs per person to 200 eggs per person will take more grain than Australia produces. So as China moves up the food chain, it's going to become an enormous sponge soaking up grain from all over the world. If we allow only for population growth and no gain in income and improvement in diet in China, by 2030 because of the absolute decline in agricultural production due to industrialization's use of cropland China will develop a deficit of about 200 million tons of grain, which compares with 28 million tons in Japan today. Two-hundred million tons of grain equals total world grain exports from all countries. The United States accounts for about half of world grain exports, 100 million tons, and all other exporting countries—Canada, Australia, Argentina, Thailand—make up the other 100 million tons. But if, in addition, China continues to move up the food chain at the rate of recent years as incomes rise, it will need to import close to 400 million tons of grain.

This is not my calculation only. Professor Zhu-Guang Zhao, who is the head of the Chinese Academy of Sciences, has said, and I quote, "If we continue to squander our land and water resources in an all-out effort to industrialize, we will face the need to import 400 million tons of grain, and even all the grain produced in the United States will not be enough to fill that deficit."

This raises two questions. One, can China afford to import massive amounts of grain? The answer is yes. Last year, China's trade surplus with the United States alone was $23 billion. That was enough to import all the grain we exported last year to close to 100 countries. So the question is not so much can China afford to import; China is not Africa, which needs more grain but cannot afford to import it. The important question is who will supply China with that much grain, and the answer is no one. What this means is that the world grain market, which has been a buyers' market for the last four decades except for a brief period in the early '70s, will become a sellers' market. The competition has been among the sellers for markets that never seem to be quite large enough. That will now change, and the competition will not be among the sellers, but among the importers for inadequate exportable supplies. And that means that instead of declining grain prices in real terms, which has been the case over the last four decades, there will be rising grain prices for as far as we can see into the future.

If I were writing a commodity newsletter and recommending purchases of futures, I would say that the first thing we should watch for is rising seafood prices. That's already occurring. Seafood prices are rising in real terms about 4% per year now for the world as a whole. The second thing I would watch is rice prices, because the producers of rice are faced not only with limited land supplies but also with severe constraints on the amount of fresh water that's available. Rice requires land and water. So rice prices will be the next to rise, and then after that wheat and then the other grains. I think we're moving into an era that is very different from the one we've known since the middle of the century. Whether it's the seafood catch per person going down, or whether it's grain prices which I think will be rising in real terms—it's going to be quite different.

Now what if in addition to China needing to move into the market in a major way to import grain we also had some effect of global warming? Then we would have real chaos in world grain markets. What I think we will soon get from China when it announces plans to import large quantities of grain, which could come literally any year now if China continues to industrialize rapidly, is a wake-up call that will create sufficient economic instability in the

world economy to convince even the doubters that the relationship between us, now 5.6 billion, and the environmental systems and resources on which we depend is in trouble. And we're going to have to address these issues in a major way. I think it will lead us to redefine security, recognizing that the real threat to our security in the future is not so much military aggression as it is growing human pressure on the Earth's natural systems and resources and the resultant deterioration of those systems, whether it's overfishing, deforestation, or soil erosion.

I think this redefinition of security will lead us to seriously consider reordering priorities, such as shifting resources out of military budgets and into expenditures for soil conservation, reforestation, family planning, investments in agricultural research, etc. I think it will underline the importance of the plan of action that came out of the Cairo population conference, a plan of action that calls for bringing world population growth to a halt much sooner and at a much lower level than had earlier been considered—between 8 and 10 billion and by 2050, rather than between 11 and 14 billion at the end of the next century. I think it's going to underline the need for national governments to do population carrying capacity assessments, to look at land resources, water resources, access to seafood, and the availability of technology to increase crop production, and begin to calculate how much food they'll be able to produce and relate it to the projected increases in population. And for many countries, I think this will lead to a rather dramatic shift in population policy.

The bottom line, if we're serious about stabilizing population and climate, is a restructuring of the global economy. At the Worldwatch Institute, we call this the Environmental Revolution. In scale, it is comparable to the Agricultural Revolution or the Industrial Revolution. The Agricultural Revolution led to an increase in population growth, altering population trends dramatically, and since then we've seen enormous growth. The Environmental Revolution, if it succeeds, will also lead to profound demographic changes in the form of a leveling off of world population growth, the reestablishment of the balance between births and deaths in the world. The Industrial Revolution was based on the shift to fossil fuels; the Environmental Revolution will be based on a shift away from fossil fuels. The other big difference is the pace. The Agricultural Revolution was spread out over 10,000 years. The Industrial Revolution began two centuries ago. But the Environmental Revolution, if it is to succeed, will have to be compressed into a few decades.

The Environmental Revolution will require leadership—strong, international leadership. And that's where Japan can play an important role. I don't think that most of you in Japan yet appreciate the economic role that you play in the world today. You are one of the world's leading trading countries. You are now the world's leading source of bilateral development assistance. If one looks at the international banks in the world today, private banks, the top 10 are all Japanese. Japan has a great deal of potential political influence in the world today related to the strength of its economy. I know that you think you're in an economic crisis now because the economy is not growing and hasn't grown for the last few years, and by Japanese standards I suppose that is a crisis. But the Japanese economy is a powerful economy, one based on a highly skilled, highly educated, hard-working labor force.

We need leadership in the population arena. No country is better suited to do this, simply because Japan itself faced a need to quickly slow population growth after the end of World War II. As an economy, you had lost access to the resources of Southeast Asia and China, and suddenly you had to rethink your future in terms of living on these resource-poor islands. And this led to a reduction in the population growth rate of half between 1948 and 1955. In seven years, you reduced your population growth by half, and that's exactly what developing countries today need to do. We in the United States cannot provide that example, because we've never had that experience. You have. You can.

Another arena in which you can play a major role is in raising energy efficiency, a major contribution to climate stabilization along with the development of renewable energy resources. But Japan is a country that has led the way in increasing the efficiency of energy use and exporting these technologies. Helping developing countries use more energy-efficient technologies could be an important contribution to the eventual stabilization of climate. Similarly, with the development of renewable energy resources there's a real need to push ahead in developing wind power, geothermal power, solar power in the form of photovoltaics, solar thermal power plants—a whole range of technologies moving very quickly where Japan could play a leadership role in development.

In conclusion, I would like to say thank you to the Asahi Glass Foundation for not only the Blue Planet Prize, which is in itself extraordinay, as Professor Seibold would agree, but also for the opportunity for the two of us to exchange ideas with you this afternoon. I would end by saying that I think Japan can play a far more important leadership role in the world today by fostering the Environmental Revolution, in leading it, if you will. This is because of the resources you have and the experiences that you have had. Again, thank you very much for this opportunity.

Follow-Up Discussion

Introductory Comment

Thank you very much, Mr. Brown. With this, I would like to invite Ms. Kei Hata to have a dialogue with Mr. Brown. Ms. Hata, after resigning from her position at NHK, served as an anchor for the "Sunday Project" program at TV Asahi. She has also been active in writing. In 1992, she was invited to Paris by the European Union as a cultural journalist and cultural coordinator. She has been very active in a wide range of areas. Please, Ms. Hata.

HATA: First of all, I'd like to thank Mr. Brown for his wonderful, enthusiastic, and very specific lecture. And also I'd like to congratulate you for winning the Development and Implementation Award.

In your lecture, you talked about the Environmental Revolution. I believe the necessity of the Environmental Revolution was described with very objective facts as well as specific examples, and I'm sure that the audience could understand your message clearly. It was a very informative lecture. About the environmental issues, I'm sorry to say that I'm not a specialist in this area. As mentioned in my introduction, I was a newscaster, and in that position I was conveying information to people. Environmental issues started to be included in the news that I was broadcasting, and I was always impressed by that news concerning the environment. At one point, a colleague and I needed to prepare a comment on the news. We could easily convey the facts, but we had questions about what sort of actions we could suggest for people to take. For example, you talked about an international leadership role for Japan, but what sort of policies should Japan have? Maybe I could say something to the government about the actions Japan should take. But we are talking about the global environment, so maybe we should look at international coordination and cooperation. But what kind of specific recommendation can we give? It was extremely difficult for us to give such specific recommendations while we were describing the environmental problems. Since I could not do it at that time, I believe that this is a very good opportunity for me to ask you the following questions.

I believe that the necessity of the Environmental Revolution was introduced by you, Mr. Brown. I would like you to talk about your specific scenario or prescription for the Environmental Revolution. Although we have limited time, I would like to try talking about this. Basically, I would like you to give us some advice or key points to solve the current problems. You've already mentioned Japan and that we have to play an international role. Could you give us any specific advice concerning Japan's role via other countries? And you talked about the grain market and other markets, especially in China. In your *State of the World,* you have mentioned the changing role of the World Bank. Fifty years after the Bretton Woods system was established, there was a major change made because of your initiative. So I'd like you to talk about the international coordination and cooperation in order to tackle environmental issues. The third point that I'd like you to refer to is what we as individuals can do. What do we need to think about, and what kinds of attitudes should we have toward environmental issues? Sometimes we talk about those issues, but we usually do not take specific actions. So as an expert, could you please give us some suggestions for action at the individual level? I'm sorry to be speaking so quickly in Japanese, and I don't expect you to respond to all three questions right away, and I'd like to ask one question at a time.

Mr. Brown earlier told me that he wanted to entertain as many questions as possible from the floor, and of course Mr. Brown is an intelligent person, and I'm sure there are many people who will be asking many interesting questions to Mr. Brown. In any case, as the second part of this program I'd like to ask Mr. Brown to talk about the prescription or specific scenario for the Environmental Revolution for about 30 minutes, and then we'd like to entertain questions from the floor. I just want to ask the audience to prepare their questions while we listen to Mr. Brown.

I'm sorry to speak for such a long time. First, about the specific scenario, especially for Japan and developed nations, what would be some prescriptions for action?

BROWN: Thank you. I mentioned earlier the world population conference held in Cairo in early September. One of the highlights of that conference, of course, was the agreement on a World Population Plan of Action to slow world

population growth sooner, and to stabilize population size at a much lower level, than has traditionally been projected. The World Population Plan of Action is probably the most ambitious initiative ever undertaken by the United Nations. I think it has the potential, for example, to dwarf the eradication of small pox in terms of its contributions to humanity over the long term. Among the principal initiatives within that plan of action was the agreement on the urgency of filling the family planning gap. The family planning gap is defined in terms of the estimated 120 million women in the world who now want to limit the size of their families but who lack access to family planning services. Simply providing them with services, which is not a terribly costly thing to do, could help reduce world population growth by perhaps one-fourth. So that would be an important contribution. Japan has already pledged $3 billion, I believe, toward that effort. The United States is making a major pledge, as are a number of other countries. But this is one of the most urgent and important things that the international community can do to help lighten the long-term pressure on the Earth's environment.

A second important component of this plan was the emphasis on the need to educate girls throughout the world. In many countries today, education for young girls is considered largely a waste of resources, so they are often taken out of school while the boys are kept in school. The unfortunate thing is that of all the social indicators that correlate with the shift to smaller families, none is more closely correlated than the level of education. Simply stated, the more education women have, the fewer children they have. And that is a relationship that holds across all cultures. This means that the world, the international community, has a stake in increasing the education of girls and making sure that girls everywhere at least have the opportunity to become literate, if not more. So this means in many cases restructuring development budgets in order to help achieve this end. So these are two specific actions that can help stabilize world population, which I consider to be the most important single thing we can do to preserve our environmental systems and resources.

If we look at what individuals can do, there are many things, of course. People have written a book entitled *50 Things You Can Do to Save the Environment.* I won't go through all 50 things, but I'll just mention a few things. Of all the decisions that we make as individuals, the one with the greatest environmental consequences is the number of children we will have. That is particularly true in a country like the United States, where the average person consumes so much and puts so much pressure on the Earth's resources. I think we have reached the point where we should now consider accepting the idea that we should only have enough children to replace ourselves—two children per couple, the two-child family. It's not that some of us might not be able to afford more than two children. The question is whether the planet can afford more than two children per couple. I think that the answer is becoming clearly no. So I think pushing for adoption of the two-child family as the social norm or goal is something we can all participate in and take into account in our own personal decisions, as well.

Probably the thing most individuals think of doing when they think about being environmentally responsible is recycling, because all of us throw things away. So the idea of recycling has become quite popular. In the United States, the growth of recycling programs in communities and cities around the country has increased so much over the last decade or so that it has greatly exceeded the capacity of industry to use recycled materials. And so it has created major problems for those recycling programs, because there's no place to send the material. Many of them set up programs to recycle, and they separate the glass and the paper and aluminum, only to discover there's no market for it, so it ends up going to the landfill anyhow.

Some things have been done to change that. For example, the U.S. government in an executive order issued about a year ago said that beginning with next year, all paper purchased by government would have to have at least 20% post-consumer waste in it, that is, it would have a heavy recycled content. Once the federal government did that, then some local governments started doing it also. Then some corporations started doing it, and suddenly there was a great demand for recycled paper, because there wasn't enough paper being recycled to satisfy the demand. A number of things happened. One, paper companies stopped building paper mills in remote forest areas like Canada or the U.S. Northwest or Maine; instead, they started building their new paper mills next to large cities. One was built near Philadelphia, for example, along the Delaware River. That paper mill now feeds on the waste paper from the greater Philadelphia area. And this has been repeated dozens of times around the United States. But such a

strong market has developed for recycled paper now that recycled paper beginning, I think, in January will be traded on the Chicago Board of Trade. So this is a major step forward where up to now lumber and wood for paper pulp were traded on futures markets, but not waste paper. This is an example of how things can change. In this case, it was a government policy, an executive order, not even legislation, but just a decision by the U.S. government in its procurement to buy heavily recycled paper. That's an example of a national policy change that can begin to make a big difference.

HATA: Mr. Brown, you have mentioned recycling. Earlier, you asked Japan and other developed nations to take leadership. In Japan, of course we are making progress in terms of recycling, but we are far behind the United States still. We were delayed or we were a slow starter. Individual awareness or consciousness is a bit different, I think. In Japan, we do not have the awareness that we have to take the initiative to make the changes. We feel that we can depend on the others, and we don't realize that we must take actions to change things. Since I was born, I think you have visited Japan many times, and I would like to ask you about your impressions of recycling here.

BROWN: Recycling is one area where Japan historically provided leadership even before the modern environmental movement. I can remember 20 years ago Japan was importing scrap metal from the United States to produce steel to manufacture automobiles. I remember hearing someone say that this year's Buick is next year's Toyota. Actually, it should be this year's Buick is two of next year's Toyotas, because the Toyotas were much smaller than the Buicks. Japan has a long tradition of recycling. But I think in recent years it may have lost momentum and not moved as fast as perhaps some other countries have. In the United States, we historically have lagged in recycling, because we had so many natural resources within our boundaries that people didn't want to think about recycling. But recently, our recycling has begun to grow rapidly, and it is in part because of the activities of environmental nongovernmental organizations.

One of the important social differences between Japan and the United States is that there is in the United States a long and strong tradition of nongovernmental groups playing an important role, and nowhere is this more important than in the environmental field. Just to cite a specific example, at the time of the Rio conference many governments in the world including the U.S. government were basing their analyses and position papers and national reports not on research they themselves had done, but on research that had been done by environmental groups. One reason that the publications of the Worldwatch Institute are so widely translated and marketed around the world is because in the official structure there is not that much good research. And the United Nations environment program, which has been severely handicapped because of budget reasons, has never evolved into a major research organization, a major source of environmental information. And so in that case, NGOs, or nonprofit research institutes like the Worldwatch Institute, in effect are providing that public service, if you will. I suppose one of the things that I would encourage here is the development of more independent voices in the society, which is one of the things that nongovernmental organizations can do. I know that there is an NGO conference that's been underway here now for the last few days, because I've been reading reports in the newspaper. But I do think that strengthening this third sector, if you will, would be an important contribution to achieving some of the goals we've discussed.

HATA: You have just referred to the newspaper articles, and you have pointed out several good aspects of the Japanese initiatives and efforts, and I'd like to discuss another article from today's *Asahi Shimbun* newspaper. In the famous column called *Tenseijingo* in this newspaper, environmental issues were touched upon. The column says that progress and development often lead to natural degradation. So we should not just focus on the extent of progress, but we should reduce the aspects of degradation from the progress that we have made, and that was an important viewpoint included in the comment. In Japan, we are now discussing some form of taxation of environmental impacts. But Japan, generally speaking, is not so active in promoting this kind of thinking, like environmental taxation to pay fees for progress. What do you think of this?

BROWN: Let me start with your last point first. Of all the policy instruments that governments have available to accelerate the Environmental Revolution, none is more important than restructuring the tax system. Using tax policy, they can foster environmentally constructive activities. For example, in the United States the principal source of revenues for governments is from income taxes. When you tax income, you tax work and you tax savings. But these are both good things, and we should not discourage work and we should not discourage savings. We should tax those things that are destructive, not those things that are constructive. For example, why not tax carbon emission from burning fossil fuels? Why not tax the generation of waste? Why not tax the generation of toxic wastes? Why not tax the use of virgin raw materials, such as wood for papermaking, or the use of mineral ores for metal production? Why not tax those, which would then favor the promotion of the use of recycled materials, for example? If we tax fossil fuels at a level that reflects their cost to the environment in air pollution, acid rain, and global warming, then we would make the market more honest, because now the market does not reflect these costs. The people in Los Angeles who drive automobiles that cause respiratory problems to children do not themselves have to pay those health-care costs. The parents of the children have to pay those health-care costs. So the market economy I think has many advantages, but one of the disadvantages is that it does not reflect the indirect costs associated with environmental degradation in many forms. So if we could restructure the tax system—I'm not talking about increasing taxes, but just changing the mix of taxes—to increase taxes on environmentally destructive activities and then reduce the taxes on income, then I think we would have some strong encouragement for more environmentally constructive behavior and we would have the means of greatly accelerating the Environmental Revolution, a way of speeding the move toward an environmentally sustainable global economy. Given the rapid drop in costs of developing renewable energy resources, such as wind power, solar thermal power, photovoltaics, etc., in some cases it would not take much of a tax on fossil fuels, one that would be designed to reflect the costs of air pollution, acid rain, global warming, etc., to shift the balance dramatically to the point where we might not see anymore coal-fired power plants built, for example.

So this is an important idea, and I'm pleased that you raised that question. The early part of your question had to do with the story in the *Asahi Shimbun* newspaper today about the fact that progress and development lead to natural degradation. It can and often does, but it need not. Indeed, one could argue that by definition something that leads to destruction of the environment is not progress, because it's undermining our future. And so if we look at energy, for example, we could increase energy production in the United States dramatically without creating any pollution if we were to invest in wind power instead of coal-fired power plants to generate electricity. This is already technically possible. In California, there is now enough electricity produced from wind farms to satisfy the residential needs of two cities the size of San Francisco and Washington, D.C., for example. Wall Street has invested more than $1.5 billion in the manufacture of wind turbines and in the actual installation of the turbines to produce electricity. The latest survey in the United States of the wind resource potential, using the latest technologies for generating electricity from wind, indicates that two states—North Dakota and South Dakota—have enough wind potential to satisfy national electricity needs. Last year, China completed a survey of its wind resources. This was a seven-year inventory of wind power potential. The study concluded that with existing wind technologies, it would be possible to triple China's electricity production. I would argue that Japan has an interest in fostering the development of wind power in China, because the alternative, coal power, will produce air pollution and, more importantly, acid rain that will affect Japan. So I think we've got to rethink the question of what progress is. Progress is not just an increase in the output of something or an increase in GNP. Progress, I think, is increasing the production of goods and services that we need without undermining our future. *Sustainable development,* as we have defined it, and the UN Brundtland Commission also used this definition, *is development that satisfies current needs without jeopardizing the prospects for future generations.* If we use that definition, then progress by definition is not an environmentally destructive activity.

HATA: Well, you have now argued the need to define progress in a new way. And I think that Japan, as well as many other countries, has to buy this argument. Listening to your discussion, I feel that you know the situation in

Japan quite well. Wind power generation will be technologically and economically beneficial. And you said that Japan has an important interest in developing wind power generation in China. And we also have been talking about recycling. You cited the case of Buick and Toyota. If recycling activities are economically profitable, then probably quite immediately there will be a strong impact from recycling activities in Japan and other countries. But if the return on this investment, namely recycling, comes quite late and not immediately, then people might not so easily change their behavior or thinking.

You have also emphasized the need to renew our value orientation and to approach the market economy from a new perspective. And it seems that we are dealing with the issues of world economy, and I'd like to turn to the issue of the global economy. You mentioned the World Bank's role and the need to move away from the conventional Bretton Woods system. Could you be more specific about this need to come to a new era of world economy?

BROWN: Let me begin with the World Bank, because it does play a central role in shaping the evolution of the global economy through its investment decisions throughout the third world. The problem with the World Bank is that it is run by economists. Economists think in terms of linear and exponential growth, and there is no basis in economic theory for thinking about carrying capacity and biological limits, for example, or the limits of the amount of water that the hydrological cycle can produce. If an economist is told that fish are becoming scarce and seafood prices are rising, his response will be a suggestion to invest more in fishing trawlers. Well, at one time that was the right advice but it no longer is, because if you invest in more fishing trawlers you simply hasten the day when the fisheries will collapse. And similarly with water.

Economists still tell me today not to worry about food scarcity, saying that if prices go up an increase of investment will follow, and everything will be fine. The problem concerns what we invest in today. Do we invest in more irrigation wells in northern China, for example, where the water table is already dropping very fast? Again, you simply hasten the arrival of the time when the aquifer is depleted. Or do you invest in using more fertilizer? But that doesn't help much with production anymore. Natural and biological constraints are not part of the economist's mindset. But fortunately, there are some economists at the Bank who are beginning to understand the need to change their thinking and to incorporate environmental issues. Another example where the Bank has been very slow to react is as follows. Up until very recently, 99% of the World Bank investment in energy was in new production, when environmentalists and others who had been working on energy knew that the return on investment in increasing efficiency would be far greater. If you're going to loan a country $1 million or $100 million, it should not go into new power plants, but should go to increasing the efficiency of existing facilities. But this is not the traditional way of thinking with economists who have been very production oriented. Recycling was not part of the economists' mindset, either, so that's been a very slow area to develop in World Bank lending. When World Bank economists think of water, they think of new projects. They don't think of investing in irrigation efficiency, which might be a far more productive use of capital. So it's that change in mindset that's needed. And it is coming at the Bank, but it's not coming fast enough.

HATA: If that's the case, we should transform the system of policymaking dominated by economists by employing more economists concerned about the environment. Is that right?

BROWN: Yes, we should employ more economists who are concerned about the environment. Unfortunately, there are not very many of them. They are one of the world's more scarce resources. Ecologically minded economists are not very numerous. Another way to approach it would be to begin to hire a number of ecologists to work with the economic advisers and decision-makers within the Bank and other international organizations. I think the world would be far better off if we were to staff international development organizations partly with economists, because we do need them, but partly with other disciplines, importantly those with biological training, including ecologists.

HATA: Is there any current trend to employ more ecologists? Is that viable as a policy option?

BROWN: It is. There is now within the Bank a new entity. It's not really a division of the Bank, but it's called the Global Environmental Fund. It has separate funding from the Bank, and it does have a number of environmental scientists, and it has tried to hire economists who understand ecology. So it is beginning to play an increasingly important role in lending programs and is providing some leadership. So there is progress. Within the U.S. government, one of the first things that the new administration did was to create within the White House an office of environmental policy, which is headed by a very dynamic young woman named Kate McGinty. This office provides environmental advice directly to the president and to the vice president and coordinates environmental concerns throughout the cabinet. So regardless of what kinds of decisions are being made, whether it's the Department of Commerce or the Department of Agriculture or the Department of Energy, there is at the top level of government an ecological input into that policymaking process. So I think this is an example of an important step in the right direction. But the bottom line is that there's a great deal of reeducation that's needed, because most of us were educated before environmental issues became important. And so we have had to learn these things from reading newspapers and magazines, from watching television newscasts, and so forth. And so we've had to sort of teach ourselves. But I hope we can incorporate this thinking into our educational systems so that in the future people who come into the job market will automatically have an understanding of these issues that our generation did not have.

HATA: Yes, a discussion of any problem seems always to lead back to education. Whenever I have a discussion of cultural problems, it seems that one always turns to educational policies and methodologies. As Mr. Brown just said, we need to emphasize new values, and based on those new values we need to establish a new and improved educational system. Mr. Brown has met with former Prime Minister Miki and former Prime Minister Fukuda, and also had time to talk with former cabinet members of Japan, and he has extended his advice to Japanese cabinet members, as well. I would like you to propose the establishment of an office of environmental policy within the Japanese cabinet. I think you are the most influential person in this field, so I'd like to ask for your cooperation, as well.

Even though I said I wanted to speak with you only 30 minutes, it has already been 35 minutes. So now I'd like to entertain questions from the floor. We are already behind schedule, but Mr. Brown would like to answer your questions, so please go ahead.

QUESTION: I am a foreign student from China. Thank you very much for your very interesting presentation. You have pointed out the population problem in China and you have shown specific data, and those are quite shocking. We have many problems in China, surely. I have also chosen environmental problems in China as my study theme, and I'd like to ask a simple question. It is true that when you talk about Chinese environmental problems, you cannot dismiss the population problem. Mr. Brown has suggested the Environmental Revolution, and I wonder what China's first priority toward this end should be. Second, there is a one-child policy in China, and I would like you to comment on this from two perspectives: the environment and human rights. Third, there is quite heated economic development taking place in China, and if we continue without any change, then is sustainable development viable?

BROWN: Thank you for those easy questions! I remember in the late 1970s when China began to seriously examine the population issue—I think it was part of the early post-Mao reassessment when projections were done for China— and the question was posed about the possibility of having only two children per couple and its effects on future population growth. Because of the age structure of the population when that was projected into the future, it showed an enormous increase in China's future population growth—the addition of perhaps another billion people. As part of that exercise, an effort was made to see what that would mean in terms of living standards. If another billion people were added in China, what would it do to the amount of cropland per person, the availability of fresh water per person, the amount of capital required to build classrooms, the availability of jobs, etc.? The leadership concluded that adding another billion people was unacceptable, because it would interfere with the effort to improve living standards. As a result of that, China initially adopted the goal of a two-child family with a delayed marriage, and then some years later adopted the goal of a one-child family in an effort to slow population growth sooner and

to stabilize it at a much lower level. I think that was the right thing to do, because the number of problems if China added another billion people would have been almost impossible to deal with. It underlines the difficulty in any country if it waits too long before addressing the population issue. And in the case of China, as you know, throughout the third quarter of this century the official position was that population was not a problem. More hands meant more production, so there was no worry. And my fear is that many other countries for various reasons are delaying too long a serious consideration of the population issue, and they will find themselves either in a position where they have to slam on the demographic brakes or, as in Ethiopia, face a rise in death rates. So the options become very difficult to select.

In retrospect, the one thing that could have been done differently in China is rather than make an absolute rule that a couple can have only one child, set up a series of incentives and design them so that the result would be an average of one child. Some couples might decide not to have any children. But it would not be an absolute thing, and if having a second child were important enough that people were willing to forego those incentives or to accept the penalties—one could do it with a combination of incentives and penalties—it would increase somewhat the flexibility. I mention that approach because that in effect is what shifting tax policy does. I was just talking about the need to shift tax policy in order to make the market more honest by taxing environmentally destructive things. But it also avoids the clumsiness of regulation. If you try to achieve all environmental goals through regulation, it really begins to restrict flexibility in a way that can have a very negative effect. But if you use tax policy as a steering mechanism, you can achieve the same goals while letting the market continue to operate. So tax policy becomes a way of sending signals to decision-makers without regulating their behavior.

There are some areas where there's no alternative to regulation. For example, if an oceanic fishery is under excessive pressure, then you may be forced to regulate and establish quotas in that fishery, or you may not be able to save it. Also, consider the disposal of nuclear waste. You can put a heavy tax on nuclear waste, but since it's so costly to get rid of some people might just decide to dump it in a nearby stream, creating serious problems. So there are some things that do have to be regulated. But insofar as possible, if we can let the market operate and use tax policy to steer it in an environmentally sustainable direction, I think it's far more efficient.

The other questions concerned whether economic development of the sort that's now occurring in China is sustainable. The answer to that is probably no. The difficulty in China now is that there is such a headlong rush toward development and increased production with almost no meaningful environmental controls or taxes or signals. So what we are seeing developing in China now is a situation similar to that which developed in Russia three or four decades ago, and I mentioned the recent report on the state of the health of the Russian people, and it is not a happy report. And I think there's a risk that China in 15 years could be publishing similar reports where life expectancy would actually be declining because of severe pollution. One of the differences between China and Russia is that Russia has a lot of space and therefore more capacity to absorb pollution than does China, where so many people and so much economic activity is being concentrated in such a relatively small area.

So it seems to me that there is a need for an important national effort in the environmental field to complement the adoption of some very successful economic policies—successful in terms of getting rapid expansion, but not necessarily environmentally responsible or sustainable. I see, for example, heavy investment in coal-fired power plants. Indeed, investors from outside are being encouraged to invest in the construction of coal-fired generating plants. I would think that that policy should be changed to encourage investors to invest in wind farms or solar thermal power plants in the western part of the country where there's a lot of desert and sunlight that could be harnessed and converted into electricity with the same types of solar thermal power plants that are generating several hundred megawatts of electricity in southern California. That technology exists, and it's becoming quite competitive. So I think there is a need for some advanced thinking. It is possible to greatly increase energy production and consumption without destroying the environment, but that component is now missing among the official policymakers in Beijing.

QUESTION: Looking to the future, do you feel that the continued pursuit of traditional water resource development policies, often centering on the construction of capital-intensive projects like dams, is prudent or even possible? Also, what changes would you like to see, if any, in international and national development and management policies regarding water resources? Last, what do you feel Japan can specifically do to lead in this area internally and externally?

BROWN: One of the reasons for developing large dams is to generate electricity. Unfortunately, this all too often means consuming large amounts of land and displacing large numbers of people. One of the best examples of that at the moment is the huge Three Gorges Dam project in China. There is an interesting new study from the World Bank by economists, incidentally, that looks at the question of land use and energy production. One of the somewhat surprising findings is that some of the renewable energy technologies, some of the newer ones like solar thermal power plants or wind farms, use much less land than do some of the traditional technologies such as hydroelectric generation from large projects. So from a land-use point of view, the development of hydropower is excessively costly. One of the attractions of harnessing wind power is that it often permits the land to have more than one purpose. For example, in the Great Plains of the United States, where there's an abundance of wind, the land may produce $30 worth of beef per acre per year, but that same land can produce $6,000 worth of electricity per year. But there need not be any conflict between those two uses, because the wind turbines do not really disturb the grasslands, so the cattle can still graze and harvest the grass even as the wind turbines are harvesting the wind.

Another exciting possibility in the Great Plains of the United States, where wind erosion is a serious problem and where we used to plant rows of trees as windbreaks to slow the wind, is that we can now use the money we invested in planting trees to build rows of wind turbines, and they have exactly the same effect: they take the energy from the wind as they slow it down and convert it into electricity. I mention this just as one example of a need to rethink our energy production technologies, specifically the generation of electricity, because with some of the new technologies all kinds of new options are beginning to develop that warrant consideration.

In order to change national and international development institutions and policies in this area, I think the most important weapon is information and the dissemination of that information. I mentioned the Bank study that concluded that developing hydropower resources leads to the excessive use of land; this is a major study and it begins to affect the way policymakers think.

The question of how Japan can lead is interesting. It seems to me that Japan is well positioned to consider a number of options for the generation of electricity. Let me cite one. Japan today is the world's leading manufacturer of photovoltaic cells. In many third world countries, in remote villages where there is no central electrical grid for the distribution of electricity it is cheaper to install photovoltaic cells in the village than it is to both build a central power plant someplace and build the transmission facilities, because you have two costs of producing the power and transmitting it. Most of the world's energy systems were developed before photovoltaics became available, and so we now have to rethink this. As I recall, there are now something like 60,000 villages in the third world that are not connected to a grid that already have photovoltaic installations to provide the basic electricity for lighting, operating a village television set, for operating a pump at the village—just minimal needs. This technology is now economically competitive with the traditional central plants with the cost of grid construction. Sometimes, just being up to date on the economics of the alternatives can help change policy. In a sense, the collection and analysis of this data and its dissemination is one of the things that the Worldwatch Institute tries to do. But there should be much more of it, because we're just one small organization trying to provide the information needed for more intelligent decisionmaking and more rational policymaking.

HATA: Economic viability should be based on and viewed from various angles. I am really interested in continuing this discussion, but unfortunately Mr. Brown has another appointment at 5:30, so we'll just have one more question.

QUESTION: I am teaching environmental issues at Japanese universities and colleges to young people. I always use the *State of the World* as a teaching material, and it is very well accepted by the students. Also, the children's version of *State of the World* is really excellent, I think. From the viewpoint of environmental education, I have a question. The Japanese have much knowledge about the environment, but they do not put this knowledge into practice. So there is a big gap between their knowledge and what they actually do. Of course, we need to begin with awareness so that children will be able to have some good experiences in the natural environment. For the children, the Japanese Education Ministry is sponsoring some environmental programs. However, what can we do for the adults in order to change their awareness? What kind of specific ideas do you have to change the thinking of adults? You have also mentioned the role to be played by NGOs. But Japanese NGOs are still in infancy, while in the United States they are quite well organized, powerful, and influential for policymaking. Also, taking part in NGO activities remains a very rare thing among Japanese. How can we include the general public in NGO activities? What are good strategies to employ to invite ordinary citizens to participate in NGOs? If you have some good advice based on your American experience, I would like to know that.

BROWN: Thank you for using *State of the World* in your course; I wish more professors would do that. In the United States, *State of the World* is now used in more than 1,000 college and university courses. It is quite widely used, partly because it deals with broad issues and partly because it's very current. We publish it each year so it remains up to date, and professors seem to appreciate that. You mentioned the children's version of *State of the World* and its use here in Japan. Japan is the only country that has a children's version of *State of the World,* thanks to Worldwatch Institute Japan and Soki Oda's leadership. I wish other countries would also produce a children's version, but unfortunately none has yet done so. Some have discussed it—France has discussed it, the Scandinavian countries have talked about it, but none of these has yet produced it.

In putting knowledge to use, I think to some degree the political tradition of a country is important. If one is born in a totalitarian state and the government, not people, make decisions which are handed down from the top, then the sense of being able to influence things does not exist in the same way that it does in a democracy, or in a country with a long tradition of democracy. Japan is not a totalitarian state; it is a democracy. But it has also been up until very recently a one-party political system, and when one party is so dominant as has been the case here with the Liberal Democratic Party, there is not so much opportunity for alternative views and policies to influence or to make an input into decision-making. I would almost be willing to project that the recent changes in the political structure within Japan and the greater diversity of parties and political participation would help people to realize that being politically active can make a difference, and that oftentimes this political activity comes from the groups not in power, and that it's a way of strengthening their position so at the next election they have a chance of taking power or at least assuming more power. I think that the realization that people can make a difference will increase as the political diversification of Japan increases.

HATA: Unfortunately, we have a time constraint, and I apologize to those others who wanted to ask questions. I'm very pleased to have had this opportunity to discuss these issues with Mr. Brown. Thank you very much, Mr. Brown, for your lengthy discussion. I felt your presentation and this discussion with you was very worthwhile. I would like to communicate your message to the Japanese people. Thank you again, Mr. Brown.

BROWN: I would like once again to thank the Asahi Glass Foundation for not only sponsoring the Prize, but also for this opportunity for Professor Seibold and myself this afternoon. Thank you very much.